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A PEER-TO-PEER (P2P) AGRICULTURAL INSURANCE APPROACH BASED ON SMART CONTRACTS IN BLOCKCHAIN ETHEREUM

ABSTRACT

Traditional agricultural insurance systems are mainly based on the relationship between two actors: (i) a farmer, who purchases a crop insurance policy in exchange for a premium paid before crop seeding, and (ii) an insurance company that provides compensation for crop damages caused by extreme weather events. Many crop insurance schemes are a mix of procedures, aiming at covering the weather risk by subsidizing (partially or totally) the insurance premium. Yet, the bureaucratic mechanisms designed to evaluate the damages related to the insured crops lead to complex procedures that result in significant delays in covering the damages and implicitly the disruption of the farms' cash flow and production processes. The insurance system decentralization based on a P2P insurance system implemented on the basis of a framework supported by blockchain technologies dedicated to agricultural insurance through a smart contract system operated on the Ethereum platform can ensure, besides a less bureaucratic agricultural insurance system, a smoother payment to the farmer in a context of social economy that diminishes farmer's distrust of the risk coverage product. The paper is intended to design a technological solution based on the Ethereum blockchain that supports a financial product to cover the production risk through a structured framework on two levels: the analysis-decision level and the payment level.

Key words: smart contract, P2P insurance, indexes, blockchain, Ethereum.

JEL Classification: Q14, Q54, G13.

1. INTRODUCTION

It is well-known that one of the most important sources of income volatility in agriculture/crop production is the chaotic distribution of rainfall and temperatures throughout the crop life cycle. The harvest losses caused by drought and by excessive rainfall result in losses worth billions of dollars to farmers worldwide and are almost always accompanied by agricultural commodity price increases, most often with dramatic social consequences. The uprisings related to the Arab

Spring of 2011 started with protests against food price increases triggered by droughts in Russia, Ukraine, China and Argentina and also by the torrential rains faced by large grain producers in Canada, Australia and Brazil. The conflict in Syria was also fuelled by a severe drought that devastated the farmland in the rural area in the year 2006 (Siddartha *et al*., 2019).

The traditional agricultural insurance systems roughly consists of two actors: (i) a farmer, who purchases a crop insurance policy in exchange for a premium paid before crop seeding, and (ii) an insurance company that provides compensation if the crop is affected by weather or economic events that finally lead to quantitative/ qualitative damages (production losses) or value losses (cash losses in the process of production sale). To evaluate the level of damages, the insurance company agents inspect the cropped area. Beyond the simplicity of the insurance process, there are great variations in terms of types of policy and level of subsidies provided for these schemes in different countries. At the same time, the insurance companies do not hoard the large amounts of money related to the premiums collected; they place the collected amounts in a series of investments instead, aiming to obtain higher returns.

Many crop insurance schemes are a mix of procedures intended to cover different categories of risks through partial or total subsidization of the insurance premium by specialized government agencies that monitor the development of crops.

Although the agricultural insurance system has an important social function as it ensures the quasi-stability of incomes from agriculture, it is not provided by public institutions, but by private financial companies that act according to the profit policies of their investors. The bureaucratic mechanisms used to assess the damages to insured crops often lead to complex procedures that ultimately parasitize the social dimension, generating significant delays in covering damages, thus disrupting the farms' cash flow and production processes.

All these aspects are reflected in various bad faith practices of the insurance companies, such as unjustified delays and not infrequently refusal of payment. Although certain companies try to reduce these dysfunctionalities through administrative measures, the negative public perception can be modified only by a deep change of the risk coverage processes.

To protect farmers' investments, governments intervene with support programs; but the level of the government subsidies is directly dependent on highly volatile budgetary policies. In the emerging countries, farmers often do not have economically viable insurance for their investment, because their governments do not have enough funding to implement such programs. Damage assessment in these countries is extremely difficult due to subjective evaluation that often expose farmers to corruption acts.

For the governmental risk cover systems, checking up the reported damages is a costly exercise, worth billions of US dollars globally, consisting of very high subsidies and administration costs. For instance, in the context of using direct payments both by the US and the EU, the crop insurance system in the US implies subsidy costs of about 13 billion dollars per year associated with administrative costs over 1 billion dollars per year (Buterin, 2016; Catlin and Lorenz, 2017; Siddartha *et al*., 2019).

To solve many of these administrative issues, international insurance corporations and international organizations such as FAO or the World Bank have turned to index-based insurance services (World Bank, 2011; Adegoke, 2017; Tripoli and Schmidhuber, 2018). This type of insurance is different from the traditional compensation forms, where payments are explicitly based on the loss measured in a specific location for a specific insured farmer. In the case of index-based insurance, farmers can opt for an index associated to the type of factors that have caused losses, such as the rainfall amount in a certain period of the crop vegetation cycle, (weather indices) or average yield losses on a large-sized area (yield indices per area). Payment is triggered when the index value falls in a tabulated range based on historical data.

This aspect proves that the index-based insurance does not protect farmers against any category of damages, but it represents an efficient tool for the situations when there is a risk at regional level (in the case of production risks on a large area) or there is a well-defined weather risk (meteorological risk) that significantly influences the production level and the farmer's income implicitly.

A key difference from traditional crop insurance is that agents are not sent to assess a specific incident related to a crop physical or value loss in the field. Insurance projects based on index assessment were conducted in India, Kenya, Malawi and Mexico (Ge *et al*., 2017; World Bank, 2011) as an antidote to the high subsidies of the traditional crop insurance schemes and to the fact that the administrative regulatory structures operate high-cost risk cover processes in agriculture, also widely exposed to acts of corruption. In the developed countries, the index-based insurance system has the advantage of eliminating the qualitative decisions involved in the calculation of damages by insurers and government agents. However, the index-based insurance system in agriculture is still constrained by the lack of capital for its operationalization. And also, the complexity of insurance processes discourages many farmers in using this form of weather risk coverage.

More recently, solving these significant administrative issues can be done through the large-scale involvement of artificial intelligence, Big Data and blockchain technologies (Scholl *et al*., 2016; Gupta and Giri, 2018; Sultan *et al*., 2018). Surveys show that almost half of the public would do nothing if they found out about fraud in an insurance process, while 24% even consider this fraud as acceptable (Foucart, 2019). The anti-fraud measures are costly and often hostile. Finally, the result is an unfair, bureaucratic and non-transparent treatment, with much higher costs than expected by farmers. Both the high costs of the insurance products and the bad faith practices can be significantly avoided by implementing a P2P insurance system for risk coverage.

The P2P insurance is a risk-sharing network, where a group of farmers, on the basis of an automatic risk assessment and monetization system, set up a common fund to cover that type of agricultural risk, under the form of a premium. The P2P insurance mitigates the conflict that arises between the insurer and the insured, when the insurer keeps the premiums that it does not pay out in claims. The P2P insurance is a particular case of parameter insurance also referred to as *social insurance*. The basic idea in P2P insurance is that a group of farmers with similar types of farms, and with common economic interests, base their risk coverage policy on a commonly accepted control mechanism, trust and transparency, thus lowering the costs related to risk coverage (weather, production, market, policy risks, etc.). This new insurance model combines the traditional insurance with the index-based insurance and allocation of compensations on algorithmic basis by using innovative technologies, providing a product at farmers' request that requires full transparency and full trust in what risk assessment and coverage means.

The participants, who share exposure to a certain category of risks, decide by vote on each decision and are free to delegate their votes to the other partners, creating a trust relationship between participants. As long as there is no central money management authority, any reimbursement payment to a partner is in fact a payment of premiums from the other partners. Although the total value of premiums is not fixed, the partners have full control over the expenses, which can be, on the average, twice as low (Herings, 2018).

Although there is one beneficiary and one or several payers for each claim, it is in the interest of each payer partner to proceed in a fair manner. Therefore, the payer sets the approach standards that would underlie the risk coverage in the event of an incident. This operation mode practically limits the conflict of interests and significantly reduces the payment burdens imposed to the insured persons.

The present paper is intended to design a technological solution based on the Ethereum blockchain that supports a financial product to cover the production risk through a structured framework for the organization and management of P2P agricultural insurance system on two levels: the analysis-decision level and the payment level. The analysis-decision level is a system of risk assessment and monetization and consists of a cluster whose nodes are used for transacting, communication and voting. The payment system is intended for the payment level and is based on the Ethereum platform. (Davis, 2018).

2. STATE OF KNOWLEDGE

The socio-economic inadequacy of classical agricultural insurance schemes requires a new orientation of farmers to a new model and practice appropriate to the current economic and technological reality. Blockchain technology in general and smart contracts in particular can generate a paradigm shift that supports an innovative type of P2P insurance based on FinTech concepts like crowdfunding.

Blockchain technology is a "mathematical structure" for data storage that limits corruption and falsification of information. According to Ariane Rodert (member of the European Social and Economic Committee, and rapporteur for Blockchain and the Single Market), blockchain technology could help re-invent the socio-economic models, thus supporting the social innovation needed to address current challenges. Gonçalo Lobo Xavier (co-rapporteur), considers that the technology behind the blockchain is a transformative force at the level of the entire society, bringing values such as trust, transparency, democracy and security.

The high pace of innovation in FinTech (European Commission, 2018), based on the large-scale use of mobile technologies, cloud computing, Big Data, machine learning, blockchain and DLT (Distributed Ledger Technology) allowed for a simplified access to funding and a significant improvement of digital banking and self-banking services.

The report of the European Commission (2018) stated that the Commission has established links with ISO/TC 307 Technical Committee on Blockchain Technology and DLT (Distributed Ledger Technology) of the International Organization for Standardization. The European standardization organizations were invited to play an important role in identifying the specific characteristics of the European Union in the use of blockchain technology. Among these roles we can mention:

- The Commission will conduct a public consultation on the digitization of information on listed companies on the EU regulated markets, on the possible creation of a European Financial Transparency Portal based on Distributed Ledger Technology (DLT).
- The Commission will continue to work on the development of a comprehensive strategy, taking into consideration all the relevant legal implications on Blockchain and Distributed Ledger Technology, which will target all the sectors of the economy and promote the use of FinTech and RegTech applications in the EU.
- The Commission launched an EU Observatory and Forum in February 2018, as well as a study on the feasibility of an EU public blockchain infrastructure for the development of cross-border services. It will be assessed whether or not blockchain technology can be developed as an infrastructure of digital services within the *European Interconnection Mechanism*. With the support of the EU Observatory and Forum on blockchain and of the European standardization organizations, the Commission will continue to evaluate the legal and governance aspects and to support the standardization and inter-operability efforts, among which the continuous evaluation of the cases of blockchain technology use and its applications in the context of the Next Generation Internet.

On April 9, 2019, 25 EU member states, among which Romania, signed the common declaration "A smart and sustainable digital future for European agriculture and rural areas" (EC, 2019), which practically reiterated that the EU agricultural sector is one of the main producers of agri-food commodities worldwide, the guarantor of food security and safety and provider of millions of jobs for Europeans, but currently facing many challenges in the field of digital technologies, such as artificial intelligence, robotics, blockchain, high performance computing (HPC), IoT (Internet of Things) and 5G that have the potential to increase farm efficiency, while improving their economic and environmental sustainability. The large-scale use of digital technologies should have a positive impact on the quality of life in the rural areas and can attract a younger generation to new agribusiness models (OECD, 2019).

The declaration is part of the efforts made by the member states to facilitate and accelerate digital transformation in the EU's agricultural sector. An example in this sense can be the analysis of the blockchain technology impact on the processes in agriculture made by the researchers from Wageningen (Ge *et al*., 2017).

The problem of the modernization of agricultural structures in Romania cannot continue to be treated starting from the historical hypothesis of "Romania's agricultural potential", an abstraction which is difficult to monetize in the absence of a system of coherent policies for the management of resources, production and agricultural markets rigorously substantiated and harmonized with the Common Agricultural Policy (CAP).

Due to the strong social character of the CAP, it is very difficult to conceive a package of policies that does not include a system of risk management and coverage that provides protection to investors in agriculture, regardless of their size and importance, as it is known that investments in agriculture are exposed to a wide range of weather, production, economic and political risks. Agricultural insurances are financial risk cover instruments provided by the financial industry, yet unfortunately very little used by farmers.

It would be beneficial for agri-business to treat the risk cover issue as a problem of agriculture, yet this cannot be achieved by agriculture itself, out of lack of financial resources, nor by the financial industry through specific products, due to the limited attractiveness of financial markets for these types of products.

Apparently paradoxically, the solution comes from the IT industry, which using artificial intelligence platforms for the assessment of multi-risks that affect agricultural businesses and delivering values of aggregated indices for various categories of risks, proposes smart contracts associated with a parameter insurance transacted in the Ethereum blockchain. This way the risk will be covered with an amount of money equivalent to the losses estimated by AI and paid through the blockchain electronic payment system. All this is done without the intervention of a third institution that approves or rejects the transaction. The "Technology of Trust" associated with the blockchain is considered by Marc Andreessen Horowitz (Netscape co-founder) as "one of the most important inventions in the history of computer science", while Walter Isaacson (professor at Harvard and Tulane Universities, USA) stated that the great missing element of the Internet was a "trust protocol". Practically, „the technology of trust" represents a modality by which a transaction is verified and authenticated, without being affected by bureaucratic practices that lead to mistrust between the insurer and the insured.

A series of important researches of the academic and technological community is dedicated to the blockchain phenomenon and its applications to the democratization of agriculture financing (Ge *et al*., 2017; Hang *et al*., 2020), but beyond all these, a form of agribusiness financing (peer-to-peer lending) can be discussed, free of excessive bureaucracy, alongside with a form of investment protection through multi-risk insurance (Cafiero *et al*., 2005) specific to agriculture.

3. MATERIAL AND METHOD

Based on the newest literature and practice in the agricultural insurance field, the paper tries to design and describe in detail a technological solution based on the Ethereum blockchain that supports a financial product to cover the agricultural production risk through a structured framework on two levels: the analysis-decision level and the payment level.

4. RESULTS AND DISCUSSIONS

4.1. INDEX-BASED INSURANCE IN BLOCKCHAIN

The parametric insurances implemented through smart contracts and transacted on a blockchain data structure such as Ethereum are forms derived from index-based insurances and generalized as parametric insurances.

Unlike conventional insurance, the parametric insurance does not indemnify the pure loss, but triggers a payment established following the occurrence of an objective triggering event, such as the farm liquidity index, which below a given level would lead to losses on all the farm business lines. This type of insurance is sometimes identified with the index-based insurance. This type of risk coverage has been present on the insurance market for about 20 years, but now with the InsurtTech technology it can reach a new level of popularity, as many companies are looking for additional risk transfer options. An example is a particular case of parameter insurance called pandemic insurance that has experienced an unprecedented demand once the coronavirus (COVID-19) pandemics broke out.

This type of insurance is not the only one that will benefit from the blockchain technology advantages, but it is probably the representative product for this class of decentralized applications. The parametric insurance uses data sources and algorithms for underwriting, claims and payments made by the policy holder based on a specific family of parameters – therefore, the parameters together with the monetization associated to the pre-established risk replace the traditional claiming process.

For instance, in Germany, Etherisc has developed a solution for crop insurance with automatic payments in case of drought or flood.

The offer of insurance companies for farmers in emerging economies is limited due to low profit margins obtained in this insurance category. Applying innovative technologies, such as Blockchain, and accepting paradigm changes in policy and risk management may result in lower operational costs and improved profit rates implicitly.

The key to parametric insurance is to find indicators that act as proxy for the type of damage that has to be covered. Once proxies are identified, the policies that should be qualitatively adjusted could be reduced to simple "if-then" situations. For instance, the value of Selyaninov index (proxy) outside the [1.4, 2] range determines the level of claims according to the production losses generated as a consequence. While production losses may be higher or lower than the specified value of payment, the insurer gains certainty in forecasting losses and the policy holder gains from the acceleration of payment. Both parties benefit from the automation of the process and as a consequence from lower costs.

4.2. PEER-TO-PEER AGRICULTURAL INSURANCE

According to the study KPMG (2019), InsurTECH consolidates a trend that in the conventional insurance system was not attractive due to high administration costs of financial products that had to cover low but highly diverse risks (e.g. production or market risks in agriculture). The high administration costs have definitely imposed the digitization of insurance processes in parallel with programs to increase IT skills for insurance consumers from the self-insurance category. This also implies the need for a cultural change and getting in line with the "sharing economy" principles. Nevertheless, the peer-to-peer insurance is a model that has significant chances of success both on mature western markets and in the context of emerging economies.

According to Investopedia, the peer-to-peer (P2P) insurance is a risk-sharing network in which a group of individuals pool their premiums together to insure against a risk. Peer-to-peer insurance mitigates the conflict that inherently arises between a traditional insurer and a policy holder when an insurer keeps the premiums that it does not pay out in claims. P2P insurance is also referred to as "social insurance". Peer-to-peer (P2P) insurance enjoys a growing interest from the insurance industry that is facing dramatic changes, mainly due to disruptive technological, economic and political changes.

In the case of conventional insurance, the insured pays the premium to the insurance company to cover the financial loss risk. If the insured event does not happen, the insurer keeps the premiums. Upon the occurrence of an insured event, the insurer pays out the claim. While this aspect reflects a state of equilibrium, at least in theory, the model encourages the insurer not to pay claims. This applies more to insurers with short-term horizon.

By contrast, in the case of P2P insurance, we must emphasize that the insured form a group of persons with similar insurance needs and each member contributes a premium to cover its potential financial losses. In the case of claims, the contribution is directed to the group of affected persons. The money left over after payments, expenses and fees is returned to the group or transferred to a charity organization. The insurance companies that operate P2P products are not interested in rejecting the insured person's claim, as the fees/commissions they charge are either a fixed percentage of the insured's contribution or a fixed percentage of claims paid.

An *escrow authority* is a third entity that is not directly involved in the transaction or contract, but is present in order to keep documents, funds or various assets safe before the transaction is completed. The terms and conditions are drafted by parties before the claim account is created. Upon the end of the validity period of the agreement, the funds will be returned to the initial owners. It is obvious that such a structure cannot be integrated into a software architecture implementing a P2P insurance product, unless this is delivered as a software service that can be integrated into a DLT. The integration of this service generates extra confidence in the progress of operations.

A P2P platform intended for covering the meteorological risks in agriculture automates payments for weather conditions unfavourable to the normal development of crops, using public meteorological data personalized for any location in the world. Basically, a common form for meteorological risk coverage is intended for various business lines (not only in agro-industry), exposed to meteorological phenomena for which investors want a sustainable income.

Using blockchain technology (data are stored and transacted in a decentralized way), P2P, Ethereum and smart contracts can ensure transaction security and user's confidentiality. The disruptive aspect of the use of technologies based on "Distributed Ledger Technology (DLT)" in InsurTECH can be also identified in the great number of start-ups globally distributed that develop P2P insurance platforms:

Black – A digital insurance company that uses blockchain to open the centralized insurance market for crowdfunding. The platform opens up to crowdfund capital investment opportunities (first-of-a kind) in stable insurance portfolios, with long-term financial profits, that so far have been accessible to insurance and re-insurance companies only.

B3i – The Insurance Industry Initiative based on Blockchain to build up a decentralized application system for a business network on the Corda blockchain platform, provided by the R3 software company.

ChainThat – Provides enterprise solutions using: Blockchain, DLT and smart contracts, which makes it possible for insurers, re-insurers, brokers and MGAs (**M**anaging **G**eneral **A**gents) to inter-operate peer-to-peer in perfect security and at high speed, with guaranteed data quality and considerable operational productivity.

Lemonade – combines Artificial Intelligence and DLT (Distributed Ledger Technology) solutions to provide insurance to tenants and homeowners starting from 5 USD and 25 USD respectively per month.

RiskBazaar – operates a platform that facilitates betting peer-to-peer with pre-defined payments, depending on the occurrence of future events. The project also develops risk contract prototypes that include betting, conditional payments and insurance contracts.

Teambrella – it uses blockchain and smart contracts to execute payments associated to P2P insurance. The members of a specific Teambrella group have associated a smart contract by which they can vote and execute transparently payments associated with each claim (Paperno *et al*., 2016).

Dynamis – is an Ethereum-based "distributed application", which means that the authority to validate or re-write transactions between participants is evenly distributed over the network. In this case, Dynamis uses Etherum to provide a peer-to-peer (P2P) insurance platform for insurance of unemployment and of other innovative niche product lines. The goal is to create a decentralized organization that re-establishes trust and transparency that are lacking at present in the insurer-insured relationship, by providing a blockchain-based consensus mechanism, which will avoid the costs and architecture of processes from the traditional operation of insurance companies.

All these solutions implement less hostile anti-fraud measures than those currently in practice as a response to the increasing volume of frauds in the insurance industry. In a McKinsey study (Catlin and Lorenz, 2017), it is estimated that from 5 to 10% of total insurance claims (we exclude here the live insurance claims) in the United States are classified as fraudulent and cost the insurers more than USD 40 billion according to FBI. The traceability of transactions in blockchain allows for a rigorous verification of the identity under which transactions were made, and the identification of possible frauds can be relatively easily located.

4.3. DISTRIBUTED DIGITAL WALLETS ASSOCIATED WITH BLOCKCHAIN

The self-organized farmer groups for risk-sharing and coverage will be next referred to as Risk-Sharing Groups (RSG). RSG has its activity structured according to the following rules:

- sets the rules for covering damages (categories of risks to be covered, related documents to be submitted in electronic format, etc.);
- signatures for the new members who join the RSG;
- evaluation of claims and approval of reimbursements;
- payment of reimbursements, made through the specialized level of the framework.

RSGs are established on the basis of farmer's option to have one or several categories of risks covered, and it is structured as follows:

- type of risk covered (e.g. weather, production, market, etc.);
- type of event covered (e.g. drought, excessive rainfall, agro-meteorological conditions unfavourable to reaching the yields envisaged by the farmer, selling prices that can lead to non-covering farmer's investment, etc.);
- social or professional affinity (such as belonging to the same community, membership in the same producer association for a specific crop type (wheat, maize, rapeseed, etc.);
- location of village/commune/county (where they live, where crops are located, etc.).

Any farmer can create a RSG and can define the initial set of rules. The risk cover process is activated with a minimum number of members joining the RSG (minimum two, implicitly) who have fed a "smart wallet" associated to the blockchain with the amounts related to the risk-sharing process.

Reimbursement payments can be made from the cryptocurrency wallets managed by each farmer. The private keys associated to these blockchain digital wallets are stored on the client systems of the RSG farmer and are never transmitted outside. At the first launch, the client application generates a key pair, i.e. the private key and the public key. The key pair is the only way to identify RSG members who manage their own blockchain wallet. This guarantees that no amount of money from the wallet can be spent without the farmer's consent. The blockchain wallet is additionally controlled by N of the M(N<M) RSG members selected through an automatic procedure.

Any RSG participant can withdraw his money with the agreement of the others, i.e. ensuring that all the outstanding premiums can be paid. When the teammate is selected as a co-signer of the digital wallet of another member of the group, the co-signature is made with the same key. The key is also used for signing requests to the server.

For the UTXO blockchain such as Bitcoin or Bitcoincash, the wallets are from P2SH category, with a redeem script using N + 1 of M signatures. N and M are selected so that the redemption corresponding to transactions is relatively short, yet with a sufficiently high security level for digital currency storage. For the teams with at least 9 active members with N = 3 and M = 8, a hacker should gain control over 4 of the 9 systems simultaneously.

For the Ethereum blockchain, digital wallets are associated with the smart contracts. The servers automatically adjust the co-signer lists by creating new addresses and initiating currency transfers to these. This represents a control over the RSG members who join or leave the group. The holders of digital blockchain wallets and the co-signers control this process in a similar way for repayments: each change of address by servers must be approved both by the wallet holder and by its co-signer.

4.4. RISK COEFFICIENT

Each new RSG member negotiates with the group to secure a value (insured value). The insured value is usually associated to farmer's maximum loss and can be secured. For certain risk cover types (for instance, production risk for a specific crop) the insurance value can be the same for all RSG members and regulated by a consensus mechanism with the team members. The insured value is limited to the maximum value of expenses that can be declared in a single application by a RSG member.

The probability of covering the value of production lost as a result of an E event, with a negative impact upon it, is obtained as ratio of expenses to cover the risk of E event occurrence to the total insured value:

$$PA_i(x = E) = \frac{C_i}{A_i}, where\ i \in RSG$$

The risk exposure of RSG members is different and targets both personal factors and group factors (a specific culture of risk-taking):

$$R_i(E) = \frac{P_i(x = E)}{\overline{P}} \cdot \frac{PA_i(x = E)}{\overline{PA}}, where\ i \in RSG$$

and $\overline{P}$ and $\overline{PA}$ are averages over RSG.

The higher the risk coefficient associated to a RSG member, the higher the premium he would have to pay. The accuracy of determining the risk coefficient of a RSG member is far from being extremely high, as we do not have the possibility to take into consideration all the factors that influence the calculation of the probability of a risk-generating event.

The risk coefficient of a RSG member is initially established by vote by the other members. When a new member joins a RSG, this must accept the risk coefficient voted by RSG.

The coefficient can be subsequently modified according to rules accepted on consensus basis. For instance, this can be automatically lowered after one year, if the RSG member has paid sufficient premiums for risk coverage, but he has not submitted any request for risk coverage during the year (he became tolerant to risk).

For standard types of risk coverage, an implicit risk coefficient is estimated algorithmically for each new RSG member. The estimation is based on data provided by applicant, publicly accepted statistics and/or rules established by consensus by RSG.

4.5. PEER-TO-PEER COVERAGE

Each RSG member is both provider and consumer of a risk coverage service on peer-to-peer basis. It is a relation symbolically referred to as:

$$ARP2P \subseteq GPR \times GPR$$

and defined as:

(1) $\forall (i,j) \in ARP2P \overset{def}{\Longleftrightarrow} ARP2P(i,j) * R_i(E) = ARP2P(j,i) * R_j(E)$

According to Paperno *et al*. (2016), the P2P (ARP2P(i,j)) coverage represents the maximum amount that iÎRSG can receive from j ÎRSG at a single request.

The correctness of P2P risk coverage is ensured by the fact that ARP2P relationship is an equivalence relationship.

Theorem: Be it a RSG and an ARP2P relationship over it. ARP2P is an equivalence relationship.

Demonstration:

Reflexivity: for i=j, $ARP2P(i,i) * R_i(E) = ARP2P(i,i) * R_i(E)$ it results that $(i,i) \in ARP2P$

Symmetry: be it $(i,j) \in ARP2P$ and $ARP2P(j,i) * R_j(E) = ARP2P(i,j) * R_i(E)$, hence Be it $(j,i) \in ARP2P$

Transitivity: If $(i,j) \in ARP2P$ și $(j,k) \in ARP2P$ are arbitrarily chosen, then

1. $ARP2P(i,j) * R_i(E) = ARP2P(j,i) * R_j(E)$
2. $ARP2P(j,k) * R_j(E) = ARP2P(k,j) * R_k(E)$

and for k arbitrarily chosen from RSG we have

$$ARP2P(i,k) * R_i(E) = ARP2P(i,j) * R_i(E) + ARP2P(k,j) * R_k(E) = ARP2P(i,j) * R_i(E) + ARP2P(j,k) * R_j(E) = ARP2P(k,i) * R_k(E)$$

The total amount intended to cover the P2P risk associated to a member i ÎRSG by all the other RSG members is the limit of coverage of i ÎRSG (LimAR):

(2) $$LimAR_i = \sum_{j \in GPR} ARP2P(i,j)$$

The limit of coverage is the maximum repayment that RSG is able to pay to a member i ÎRSG at one request. The coverage limit is different across members and it can be automatically adjusted over time. Although the detailing of computational algorithms and the implementation technologies are not the object of this study, we must mention a few limitations for RSG members:

- The liability of a RSG member never exceeds the volume of the cryptocurrency he holds (in the digital wallet).

- It is not possible for a member of the group to predict the exact total amount of payments corresponding to the premium in a given time frame. The expenditure control method is based on establishing a fixed amount allocated to the premium. An alternative would be that the team can agree on a rule for limiting the payment of the premium to a given percentage of the volume of cryptocurrency in each member's digital wallet. This guarantees the existence of funds to cover future incidents, after the reimbursement of a single major request.
- According to the equilibrium rule (1), the maximum that a member of the group can be obliged to pay to another member is related to the P2P coverage of the other party.
- If the P2P coverage value associated to a group partner guarantees the coverage limit equal to the insurance value, this cannot be extended.

4.6. COVERAGE RATIO AND REQUEST FORMULATION

When the coverage limit is lower than the insurable value of a member of the group, a partial insurance is taken into consideration. In the case of an incident, the expenditures made by the respective member of the group must be reimbursed proportionally with the coverage rate (CR) calculated as follows:

$$CR_i = \frac{LimAR_i}{VAS_i}$$

where i∈RSG, CR_i is the coverage ratio associated to member *i* of RSG, $LimAR_i$ is the coverage limit according to (2) and VAS_i is the insurable value. The coverage ratio of a member of the group must be visible on the platform at any moment. This makes it possible for the respective RSG member to know the reimbursement amount he/she can get in the event of an incident.

When an incident, in the category of those covered by the insurance, is reported by a member of the group or by an AI application, all the other members of the group must be notified that a claim for compensation has been formulated. These discuss the application, and the applicant or the AI system must provide information on the causes of the incident as well as on the damages produced. The voting process ends automatically in a few days. The result of the vote and the list of votes cast are available for all the members of the group at any moment as long as the voting process is active. If the applicant has not convinced the other members of the group of the validity of the claim and the result of the vote is not positive for him, the applicant may extend the voting period if allowed by the RSG rules.

The expenditure estimation process differs radically from production losses due to unfavourable weather conditions to those due to economic policies that may cause financial losses leading to the impossibility to cover the farmer's investment.

Each of them requires big data collections and high-performance machine learning algorithms, for the most accurate estimates of losses, which should not be influenced by subjectivity. Through **ChainLink** solutions, as a decentralized Oracles service, external blockchain data services can be accessed for a superior assessment of damages.

4.7. VOTING, REIMBURSEMENT AND PAYMENT

The claimant will provide an estimate of expenses that limits the maximum reimbursement. If the team has established a deductible value through the rules of the P2P platform, or if the coverage ratio of the *k*∈*RSG* applicant is not 100%, the maximum reimbursement will be automatically reduced through the following formula:

$$MaxReimb_k = (ClmExp_k - DedExp) * CR_k$$

where $MaxReimb_k$ is the maximum reimbursable value for the *k*∈RSG applicant, $ClmExp_k$ are the expenses claimed by the *k* applicant, and CR_k is the coverage ratio of *k*.

The quorum can provide any amount from 0% to 100% of the maximum reimbursement. The exact value or reimbursement is determined by voting:

$$Reimb_k = MaxReimb_k * ResVot_k$$

where $Reimb_k$ is the reimbursement, $MaxReimb_k$ associated to *k* and $ResVot_k$ is the median value in the distribution of votes. The share of a quorum member's vote is proportional to the total amount of premiums paid by him for a history of several months. The use of the median value decreases the impact of a possible tactical vote.

The contribution of each voting member of the group is calculated during the voting process, so that each member of the group has the possibility to see this in real time:

$$Contrib_{i,k} = Reimb_k * \frac{ARP2P(i,k)}{LimAR_i}, where\ i \neq k$$

At the close of voting, the platform generates a family of blockchain transactions (for Bitcoin) or smart contracts (for Ethereum) based on the volume of cryptocurrency stored in the digital wallets distributed to team members to the address of payment requester. A digital wallet holder can initiate a withdrawal transaction. The servers approve the transaction if the Remaining funds in the wallet are sufficient to pay the group members premiums for all payments non-disbursed so far. The server (servers) transmits the transaction output to the digital wallet holder and to each co-signer of the wallet.

5. CONCLUSIONS

We have proposed a risk cover system through a category of innovative peer-to-peer financial products. The users of the system can create or join a team, where each member is represented by a node (peer). Each peer is both provider and consumer of premium coverage and payment services, which in fact represents a partial reimbursement of a claim. The nodes (peers) manage, in a collective manner, all the operations of the group by vote. To streamline the voting process, "chain proxy voting" is used (Paperno, Kravchuk, & Porubaev, n.d.), and voters will be compensated for the time allocated to the decision-making process. Ethereum distributed wallets are used for payment systems, which prevent expenses unconfirmed by the group. The distributed wallets are not centrally controlled and can be migrated if hardware or software incidents may occur.

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