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# CATASTROPHIC BONDS AS A FINANCIAL INSTRUMENT FOR RISK MANAGEMENT – POSSIBILITIES OF UTILISATION IN THE AGRICULTURAL SECTOR

## Abstract

*The issue of risk management is important in agriculture because production variabili-ty of the results is dependent on several natural factors. Given the negative implications of the financial interventionism, associated with subsidizing agricultural business insurance, or „offering" disaster compensations (*ad hoc*), a deeper utilization of market or quasi-market risk management instruments, including catastrophic bonds (CAT) may be noted. This article assesses the potential utilization of CAT as instruments for risk management in agriculture, with a particular attention to the situation of the sector in Poland. The research objectives are as follows: (1) to discuss tasks of modern agricultural policy in the process of catastrophic risk management in agriculture, (2) to presence of mechanism of CAT, (3) to evaluate possibili-ties of utilization of CAT in agriculture in the light of the results of foreign empirical studies. Sustainable development of the agricultural sector is possible, among others, due to its link to financial infrastructure. Promoting risk management tools offered by the private sector or the form of public-private partnerships should be recommended. The underdevelopment of the fi-nancial infrastructure, offering innovative risk management instruments (including CAT) indi-cates the urgent need to introduce regulatory changes (including the area of good governance), to facilitate the introduction of new tools on free-market principles. Prudent utilization of innovative financial instruments should be regarded as a positive quality change. This forms an incentive for further structural changes in the Polish countryside. Through a deeper network-ing between research institutes operating for agriculture and its surroundings, as well as the entities constituting the infrastructure risk management in agriculture, the process of collecting and analyzing the data necessary for the pricing financial instruments related to, catastrophic risk management in agriculture (including CAT) would be possible.*

**Keywords:** catastrophic bonds, financial instrument, risk management, agricultural sector, disaster, indemnity.

## Introduction

The specificity of the agricultural production (as opposed to industrial activity) is its strong link with natural factors, as well as extraordinary seasonality (Theuvsen L. et al. 2014). It should be noted that long production cycles of agricultural articles (unprocessed), as well as specific hysteresis of the supply of these articles intensify price fluctuations and, consequently, the market risk in agriculture increases (Qi L., Xian Ch. 2013). The agricultural sector is particularly exposed to incidents closely related to the disaster/catastrophic risk, whose distinctive features are: (1) very low probability of occurrence, (2) damage with extremely large sizes and spatial coverage (Ogurtsov V.A. 2008; OECD 2010; Frentrup M. et al. 2011). Taking into account the probability of the occurrence of damage, as well as the size of the loss, the catastrophic risk is treated by managers as "existence-threatening" (in German existenzbedrohend) for the farm. In view of the above, it is difficult to introduce market solutions making it possible to counteract the consequences of this risk category[1].

The issue of risk management is particularly important in the agricultural sector because production variability of the results is dependent on many natural factors. Particularly important is management of catastrophic risk associated with the occurrence of disaster events, of weather and climate or geological nature, in a form of plant infectious diseases or epidemic animal diseases (plagues). As stated by V.A Ogurtsov et al. (2008), events related to the catastrophic risk can lead to the loss of an ability to generate cash flows from operating activities, and – consequently – to the permanent loss of financial liquidity.

According to M. Bac (2011), disaster events occur also in Poland, which is the arena for many types of natural disasters (floods, droughts, hailstorms, hurricane winds forming whirlwinds), typical of temperate/continental climate. From the perspective of an insurance company, it is important that the implementation of this risk type entails a need to provide compensation to many insured people in the same period. Consequently, it is necessary to provide exceptional financial requirements, which refer to the entire insurance sector, even on an international scale (Ronka-Chmielowiec W. 2010).

[1] Desirable agricultural policy measures, focused on risk management, include, inter alia: (1) support for "starting up" insurance markets (including the reinsurance segment), removing distortions in the functioning of the market, including those resulting from the asymmetry of information; (2) weakening incentives making the farmer achieve benefits in the insurance process (including the search for economic rent); (3) seeking a compromise among various objectives of public intervention: equilibrium between tools neutral for the prosperity in the countryside, and, on the other hand – the instruments significantly affecting the farmer's production decisions (OECD 2011).

In the event of catastrophic losses, it is not possible to stop (retain) the risk, as it would require the accumulation of significant financial reserves, simply unobtainable for agricultural producers (Klimkowski C. 2007). On the other hand, the lack of interest in the market instruments of risk management in agriculture stems from perceiving various forms of ad-hoc aid as a substitute for market insurance instruments. We should also take into account, as indicated in the Anglo-Saxon economic literature (Miranda M.J., Glauber J.W. 1997; Just R.E. et al. 1999; Coble K.H., Knight Th.O. 2002; Chavas J-P., Boumara-Mechemache Z. 2002), the economic universals, regarding to the market of agricultural property insurance, inter alia, moral hazard, negative selection, transactional costs related to concluding agreements. Financial interventionism, associated with subsidising agricultural business insurance, or "offering" disaster compensations, entails negative consequences, primarily related to the distortion of the production structure, it also discourages managers from taking well-thought prevention operations (in ex-ante categories). In the perspective of the next several years, there may be a turn towards market/quasi-market risk management instruments, including catastrophic bonds (Soliwoda M. 2013).

The objective of the paper is to attempt to assess the possibility of using catastrophic bonds (CAT) as a risk management instrument in agriculture, with particular consideration given to the situation of this sector in Poland. As part of implementing the main objective, the following working tasks have been adopted: (1) highlighting the tasks of the modern agricultural policy in the risk management process in agriculture, (2) presentation of the mechanism of operation of catastrophic bonds, (3) identification of the possibilities of using catastrophic bonds in agriculture in the light of the results of foreign empirical studies. The central point of reflections is the following argument: catastrophic bonds, as market financial instruments, while not crowding out existing tools, enable – at the micro level – the stronger involvement of farmers in risk management processes, with the reduced scale of the state financial interventionism. The article has a form of theoretical considerations, supported by conceptual elements (e.g. with regard to comparing various risk management instruments). The entire paper ends with the conclusions and recommendations on the possibility of adapting catastrophic bonds to Polish agriculture. The article is a contribution to the further empirical studies on the financial aspects of catastrophic risk management in agriculture.

## Disaster events as a challenge for the modern agricultural policy

The starting point for further considerations will be, in accordance with the historical approach in economic sciences, to point to the great crises in agricultural markets caused by natural disasters. As noted by H. Landreth and D.C. Colander (2005), Malthus stressed all types of restrictions "maintaining the population growth at a rate consistent with the growth rate of food supply". Malthus identified preventive and repressive restrictions. In this first group, this

prominent economist included, inter alia, increased mortality of the population caused by hunger and diseases, thus events being, in fact, the consequences of typically catastrophic phenomena. Every occurrence of this type of events (e.g. Great Famine in Ireland in the years 1845-1849) was associated with very negative, long-term social consequences which were not removed by the public policy instruments operating then (cf. Irish Potato Famine 2014).

Still, a significant issue in the economic policy of the developed countries (USA, Canada, EU countries) is to define the socially and economically justified level of the financial interventionism in the agricultural sector. One of the themes that justify State intervention in agriculture is the so-called "contemporary agrarian question"[2]. A. Czyżewski (2006) defines this problem as a kind of "syndrome of structural maladjustment of agriculture", related to the mismatch between the mechanism of functioning of agriculture to the environment. When considering the stages of the global financial interventionism in agriculture, the economist stresses that the third (last) stage, leading to agriculture integrated with the rest of the economy, will be possible through implementing market risk management instruments, as well as through deepening the integration processes (both vertical and horizontal). Countering the negative consequences of disaster events was and is a complex issue for agricultural policy makers but also for the institutional environment of the agricultural sector. Extensive experience in constructing risk management instruments in agriculture is held by the USA[3], Canada[4] or Western European countries[5]. Also, the European Union bodies and,

[2] It is also the title of one of the publications by J. Wilkin (cf. Wilkin J. 1986), in which the author refers to the agricultural sector which becomes almost a "brake" for the socio-economic development of the state. The agrarian issue is manifested by, inter alia, the lower labour productivity in agriculture, as well as the productivity of other production factors, when compared to other sections of the economy. The agrarian issue is one of the leading topics of a discussion led by the Polish agricultural economists.

[3] J.W. Glauber and K. J. Collins (2002) presented meticulously the changes in the federal legislation of the USA as regards agricultural (property) insurance. The emergence of large-scale disasters (e.g. great drought in the Midwest in 1988, floods in the Central USA), having a negative impact on the production results of the American agricultural sector, made the politicians discuss the substitutability of the disaster payment and subsidised crop insurance programmes. In the disaster payment programme (so-called Supplemental Revenue Assistance Payments Program of 2008), a prerequisite for receiving payments is the so-called qualifying crop loss of 10% with respect to a given area (Smith V., Glauber J., 2012).

[4] The evolution of the agricultural (business) insurance system in Canada is contained in the paper by M. Soliwoda (2013). The current system of programmes focused on risk management in Canadian agriculture includes, in addition to AgriStability and AgriInsurance, also AgriRecovery – allowing to launch disaster payments (to cover extraordinary losses, and consequently, to maintain the farm production potential), financed jointly by the Federal Government and the provincial authorities (Agriculture and Agri-Food Canada 2014).

[5] According to A. Garrido and A. Bielza (2008), it is possible to identify two types of models due to the range of risk management tools under the safety net: (a) model I (present in the Northern countries, with the exception of Austria), supporting training, improvement in the competitiveness of the insurance sector, regulations activating the free market mechanism, disaster payment and compensation programmes in the case of deep crises in agricultural markets; (b) model II (in the Mediterranean countries, as well as in Austria), which supports the subsidised development of crop and livestock insurance, as well as the gradual departure from *ad hoc* payments so as to promote innovative forms of insurance.

above all, the European Commission, are not indifferent to risk management in the agricultural production. Shaping the framework of instruments for management of this risk is a responsibility of the Common Agricultural Policy (CAP). It should be noted that there is a trend to depart gradually from providing *ad hoc* aid and subsidising crop and livestock insurance for the benefit of a holistic approach covering various risk categories (Pawłowska-Tyszko J. 2009) to support the agricultural income stabilisation mechanism within the framework of direct payments (first pillar). A special role is played by the instruments supporting risk management within the framework of the second pillar[6]. It is worth stressing that so far many existing risk management tools have been associated with a significant commitment of national public funds. As a result, particularly promoted are forms with the commitment of the free market mechanism, e.g. *mutual funds* associations (cf. Sulewski P. et al. 2014).

The intervention tools of the modern agricultural policy – focused on limiting the aftermath of catastrophes – are based on theoretical and practical achievements, so-called crisis management. A general algorithm of intervention of the public authorities in the case of a disaster event is shown in Fig. 1. It should be noted that of importance here is a network of links between the strategy, ability to predict crisis situations, as well as cooperation of various bodies (e.g. inspections) in accordance with the principles of *good governance*.

## Essence of catastrophic bonds as a financial instrument

As noted by Ch.M. Levis i K.C. Murdoc (1999), historically, the losses in the economy caused by natural disasters were covered by various mechanisms, including the system of private insurance, capital market instruments, financial support at the regional (federal) or central level. From ancient times, either self-insurance or compensations paid by charity organisations have been used. The amount of future losses due to disasters depends greatly on the degree of ex-ante risk mitigation[7]. Essentially, the purpose of the instruments offered or at least supported by policy makers is to reduce the negative impact of catastrophic phenomena on social prosperity.

[6] References to the issue of risk management in agriculture were included in the Rural Development Programme, also in the draft for the years 2014-2020 (RDP 2014-2020), which has been developed pursuant to the European Union legislation, mainly the Regulation of the European Parliament and of the Council (EU) no 1305/2013 of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005 and draft implementing acts of the European Commission. The draft for the years 2014-2020 takes into account *a continuation of support allowing to restore the agricultural production potential damaged by natural disasters and catastrophes, as well as the introduction of a new range aimed at protecting farms against this kind of events* (Rural Development Programme 2014-2020, 2014).

[7] In turn, the effectiveness of the instruments related to risk mitigation depends on the allocation of catastrophic risk factors in space, as well as the way of its financing.

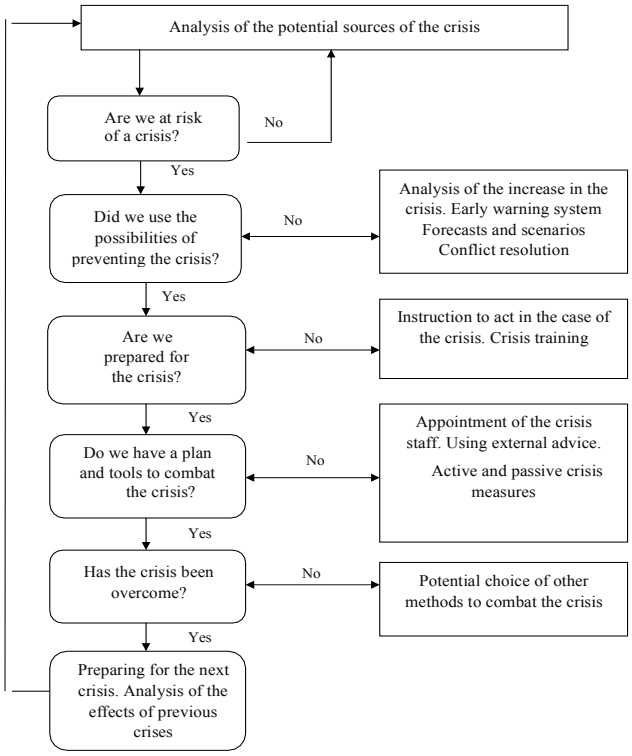



*Fig. 1.* Concept of the public crisis management system
Source: Own study based on (Doluschitz R. 2011).

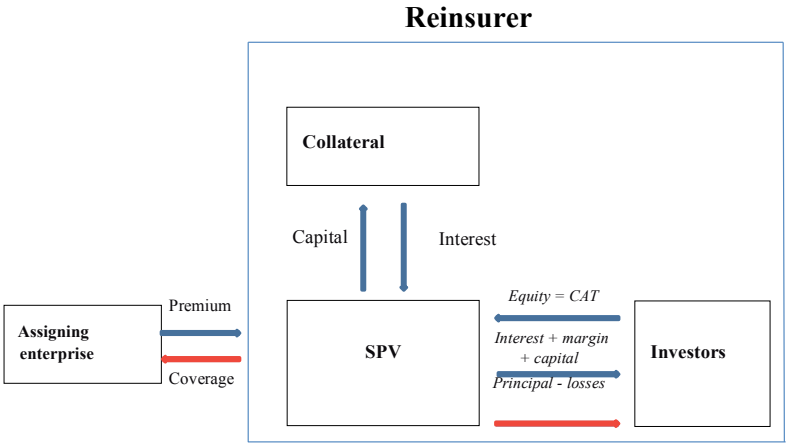
With the collapse of the Bretton Woods agreement in 1971 there was an increase in the volatility of the financial markets all over the world[8]. As a result, the participants in these markets started seeking solutions enabling risk management by means of various strategies (Preś J. 2007). There has been a rapid development of the theory of finance[9], and new financial instruments were created (primarily derivatives which were already used in agricultural exchanges in the Kingdom of the Netherlands as early as in the 17th century[10]).

[8] The essence of this collapse was the suspension by the USA of the convertibility of the dollar into gold for foreign central banks, combined with its devaluation by about 10%. After the second devaluation, in 1973, the majority of the developed countries introduced floating rates (Herbert J. 2004).

[9] This is confirmed by the golden age of finance, particularly visible in the second half of the 20th century, inter alia, the option pricing theory developed in 1973 by Black, Scholes and Merton, the concept of capital market model developed also in 1973 by Ross, or the ARCH model by Engle of 1982 (Jajuga K., Jajuga T. 2008).

[10] K. Jajuga (2008) stresses that derivatives – as the fast-developing group of financial instruments – have contributed to the development of the modern global financial market. The essence of the protection against the market risk was that beneficial changes in the value of a derivative constituted compensation for the unfavourable changes in the value of an underlying.

Catastrophic bonds are a specific debt instrument, related both to the financial market *sensu stricto*, as well as to the insurance sector. The origins of catastrophic bonds (the 90s of the 20th century[11]) are closely linked with the crisis of the limited so-called "insurance capacity", i.e. the total capacity of the market to pay potential damages (Epperson J.E. 2008). Alternative risk transfer instruments include a very wide range of tools, including catastrophic bonds allowing to transfer "a part" of the risk from insurers, reinsurers, companies to investors present in the financial markets (Härdle W.K., Lopez Cabrera B. 2007; Epperson J.E. 2008). When considering the mechanism of operation of catastrophic bonds, it should be stressed that in the case of debt instruments, debt is transferred between two parties to a transaction. In addition, the issuer may stop paying interest, when it incurs losses resulting from a disaster. It is essential that the state, company or organisation may gain access to external financing in the event of the occurrence of disaster phenomena.




Explanations: red – flows in the case of a catastrophic event, blue – flows in the absence of a catastrophe.

*Fig. 2.* Cash flows in catastrophic bonds (CAT)

Source: Study based on: (Härdle W.K., Lopez Cabrera B. 2007).

The mechanism of operation of CAT bonds is shown in Fig. 2. According to K. Härdle i B. Lopez Cabrera (2007), the mechanism of operation of catastrophic bonds requires the presence of the following entities: (1) "sponsor" or assigning enterprise (government agency, insurance company), (2) special purpose vehicle (SPV), (3) investors (institutional, insurers, reinsurers, hedge funds), (4) collateral. An entity being the "sponsor", for example, the state

[11] A. Nell and M. Richter (2005) discuss the instruments, offered as early as in the late 1992 at the Chicago Board of Trade (CBOT) exchange, namely, futures contracts on indexes related to losses caused by natural disasters, as well as related options.

supporting the development of market risk management instruments starts up an SPV, which is not a public company, but an independent entity. The state authorities (e.g. through government agencies) conclude an insurance contract, in which the "sponsor" provides reinsurance premiums to the SPV being the competent issuer of CAT bonds. These premiums serve to increase capital used as a form of collateral against the adverse financial effects of natural disasters. The issuer sells a bond to the participants – investors of the capital market. Obtained revenues are then deposited in collateral account, gathering the proceeds from assets, interest on which (variable interest rate) shall be paid to the SPV. The "sponsor" concludes a reinsurance or derivative-based contract with the issuer and pays a premium. The SPV provides coupon payments (e.g. quarterly) to the investors. The premium, and the proceeds obtained by the SPV from the collateral, are a source of interest and coupons provided to the investors. If there is no trigger event, the SPV provides the principal with the last coupon or interest payment. In other case, the SPV provides it to the assigning entity in accordance with the reinsurance contract. The investors may receive partially the principal and interest (Härdle W.K., Lopez Cabrera B. 2007; Epperson J.E. 2008; Mechler R. 2004).

If the funds for compensations are to be launched, required is the so-called "trigger" for catastrophic bonds (Härdle W.K., Lopez Cabrera B. 2007). There are various types of this activating factor, namely:

– *indemnity trigger* – launch based on the current loss as a consequence of catastrophic events. The mechanism of this kind of bonds is, therefore, similar to traditional insurance products;
– *industry index trigger* – the company recovers a part of the losses based on average losses determined for the given industry sector above a fixed point;
– *pure parametric index trigger* – payments take place with the specific and defined physical parameters of a catastrophe (e.g. wind force, position and strength of earthquake);
– *parametric index trigger* – the index covering a set of weighted many physical parameters, reflecting the exposure of the entity to losses resulting from a catastrophe;
– *modeled loss trigger* – physical parameters of a catastrophe are used in a mathematical model to estimate expected losses in the production portfolio of the company; the loss above the specific threshold, estimated in the model, launches the mechanism of catastrophic bonds;
– *hybrid trigger* – combined method, combining several activating factors.

The literature (Lewis Ch., Murdock K.C. 1999; *Catastrophe Modeling*... 2006; Hommel U., Ritter M. 2005) indicated the following advantages of using catastrophic bonds as a collateral against the catastrophic risk: (1) providing the long-term protection against the effects of the catastrophic risk, with the stable price of

the instrument[12]; (2) guaranteed expected payment[13]; (3) capital obtained as a result of issuing catastrophic bond is easier to manage than a government reserve intended for removing the effects of disaster events. This implies a conclusion that the holistic approach with regard to risk management in agriculture should also include the deeper integration of this sector into the capital market acting as a reinsurer, taking into account the occurrence of the high level of the systematic risk.

## Catastrophic bonds as risk transfer instruments and the specificity of agriculture

It should be noted that modern agricultural policies have developed a number of various risk management instruments, which should include: all regulatory solutions and multi-annual agreements/contracts (e.g. tax reliefs for farms affected by a natural disaster, subsidies to credits for the reconstruction of the farm production potential, legislative acts supporting the processes of reconstruction after destruction), coordination tools[14] (e.g., related to the functioning of the food safety inspection authorities in the "from farm to fork" chain), as well as risk transfer instruments (including catastrophic bonds, futures contracts and options related to the occurrence of disaster events). In addition to the above-mentioned instruments, behavioural biases of natural persons[15] and wrong perception of risks can be mitigated by various institutional solutions, including public-private partnerships.

Table 1 in a simplified way shows the assessment of the main categories of risk management instruments in agriculture, taking into account three essential criteria (i.e. long-lasting impact of the incentive effect on agents of economic decisions; burden for the central budget related to the cost efficiency, as well as to the level of administrative and operational costs; distortions of market mechanism, e.g. changes in the production structure). It should be noted that there is no "ideal" category of risk management instruments. Quite adversely were assessed the regulatory solutions covering the system of subsidies for crop and livestock insurance, which results from creating a significant burden on the central budget. In the vast majority of instruments under the regulatory solutions, there is also a short-term impact on economic decisions made by farm managers. More promising is the assessment of risk transfer instruments (including CAT): a positive characteristic is, first of all, the fact of not making significant distortions in the functioning of the market mechanism (agricultural sector).

[12] Typically, the insurance contract, covering one or more risk factors – in the case of crops and livestock, regarding a period of one year. The price of an insurance product is subject to strong fluctuations, when compared to the purchase price of catastrophic bonds (which is relatively stable).

[13] Funds obtained from issuing catastrophic bonds may be invested in "risk-free" assets e.g. treasury securities and bonds.

[14] In general, they are used to mitigate the negative consequences resulting from the asymmetry of information.

[15] Behavioural biases include heuristics (simplifications in making economic decisions) associated with the budgeting, the "safety-first" behaviour, hyperbolic discounting, myopia in making economic decisions, as well as procrastination i.e. postponing decision-making (cf. Kunreuther H., Heal G. 2012).

Table 1

*Risk management instruments and their assessment from the point of view of their possible application in agriculture*

| Criteria | Regulatory solutions | Political coordination tools | Risk transfer instruments |
|---|---|---|---|
| Long-term impact of the incentive effect on agents of economic decisions | ↑ | ↑↑ | ↑↑ |
| Burden on the central budget: the level of administrative and operational costs | ↓↓ | ↓↓↓ | ↑↑ |
| Distortions of the market mechanism | ↓ | ↔ | ↔ |

Explanations: upward arrow – beneficial from the point of view of the possible use in the agricultural sector, downward arrow – adverse, two-sided arrow – impact neutral or difficult to determine, the number of arrows (1-3) – strength of importance.

Source: Own study, the division of catastrophic risk management instruments categories according to: (Kunreuther G., Heal G. 2012).

Table 2 summarises the results and conclusions of the empirical studies on the possible use of catastrophic bonds. J.E. Epperson (2008) considered the hypothetical introduction of catastrophic bonds for farmers specialised in the production of peanuts[16]; he limited those studies to the state of Georgia. In turn, two economists from Humboldt Universität zu Berlin, W.K. Härdle i B. Lopez Cabrera (2007) carried out the so-called calibration of the pricing model for catastrophic bonds, whose trigger was the strength of an earthquake (with the parametric trigger). In 2006, the Mexican Government decided to participate in financing catastrophic bonds, taking into account the high level of transparency and functionality in terms of compensation payments (especially in the case of large-scale earthquakes). Summing up, in designing catastrophic bonds for the agricultural sector it is important to carefully determine the type and threshold level of the so-called trigger, as well as to adopt an adequate mathematical bond pricing model. It is also necessary to have a set of reliable and verified historical data (at the level of regional units). Thus, not without significance remains the private sector cooperation with government agencies, as well as with the network of research institutions specialised in monitoring of agriculture in terms of its environment and natural conditions.

Securitisation of the systemic risk clearly distinguishing the agricultural production by means of issuing catastrophic bonds may prove effective. As shown by the results of the studies by Z. Shen and M. Odening (2012), issuing this kind

[16] Federal Crop Insurance Corporation (FCIC) recorded the highest compensations (per 1 ha) among all crops in the state of Georgia.

of modern financial instruments proved to be an interesting alternative to the regional diversification in the amount of insurance premiums[17].

J.R. Skees et al. (2008) and also O. Mahul (2001) stressed that an alternative reinsurance tool for insurance companies may become catastrophic bonds (CAT) or weather derivatives, thus enabling the direct transfer of systematic risk from the "exposed sectors" to financial markets. Due to the high expected rates of return on these instruments, as well as the low level of correlation with the rates of return on other capital market instruments or stock indices (Litzenberger R.H. et al. 1996), CAT bonds based on indexes as the trigger are an attractive instrument for investors. It should also be stressed that catastrophic bonds are already used in practice (though they apply to non-agricultural sectors of the economy). This implies a conclusion that there are potential opportunities for their adaptation as risk management instruments in agriculture (Vedenov D.V et al. 2006; Turvey C.G. 2008). The issue of pricing and designing the system of issuing CAT bonds for agriculture remains still an open question (Shen Z., Odening M. 2012).

New alternative risk transfer instruments were developed in the 90s of the 20th century. An intention was to, first of all, transfer (at least partially) the level of exposure of the insurer or insurance broker to the catastrophic risk. Payments related to catastrophic bonds are closely linked to the frequency of catastrophes, which, consequently, is a kind of a hedge strategy and enables the prevention against the risk of insolvency of an insurance institution. It should be noted that the popularity of CAT even in the countries with highly developed financial markets (e.g. USA) is relatively low. The reason for this state should be assigned to the mechanisms indicated by the psychology of economics (finance). For example, V. Bantwal and H. Kunreuther (2000) identified a set of factors which determine the fact that the catastrophe bond market is still not fully developed. The authors pointed out that the spreads in this market are too high, making it difficult to explain it using the theory of finance, and, on the other hand, is a kind of paradox related to asset pricing[18].

[17] According to Z. Shen and M. Odening (2012), excessively simplified assumptions on the farmer's production portfolio, insurer and capital markets may affect the so-called farmers' willingness to pay for the insurance policy. In the event of catastrophic bonds, important is the impact on the so-called insurer's willingness to accept prices (WTA). Different are also farmers' expectations as to the purchase of insurance instruments depending on the type of farm production.

[18] Bandwal and Kunreuther pointed out that the extremely high rates of return may indicate that there are quite complex organisational and economic problems, that should be resolved before the catastrophe bond market evolves into the more developed form. Among the potential reasons explaining the reluctance of institutional investors to entry a new segment of the financial market can be behavioural factors, such as: "ambiguity aversion", "myopic loss aversion", fixed costs of education. In addition, we should also pay attention to the concerns of managers (agricultural enterprises) as regards the loss of repute which results from making investments in a not much popular financial instrument. Short-term incentives encouraging managers differ considerably from the long-term reasons.

Table 2

*Catastrophic bonds in the light of the selected empirical studies*

| Specification | USA | Mexico |
|---|---|---|
| Authors | J.E. Epperson, 2008 | W.K. Härdle, B. Lopez Cabrera, 2007 |
| **Selected methodological assumptions of the studies** | • There is one hypothetical insurance company, SERVO; one special purpose vehicle (SPV), farms are specialised in the production of peanuts.<br>• Bond pricing with the use of historical yields at the regional (state) level in the southern part of the USA (Georgia).<br>• Bonds' maturity is 1 year, they provide compensation for various losses (drought, flood, insect attack, epidemic diseases).<br>• Trigger – of index nature – as a percentage deviation from the average yield at the state level (e.g. below 50% of the average for the period of several years).<br>• Function of payoffs: function of the percentage yield loss, constant for each contract concluded with the farmer. Also the face value and the interest premium are determined.<br>• The expected yield losses shall be determined on a basis of the probability of the yield distribution at the state level. Given that the distribution of peanut yields for all years is not known, the estimates are based on the limited historical data.<br>• **Distribution of yield losses**: it was necessary to separate the yield risk from the deterministic trend, and thus it is necessary to decompose the time series while identifying the development trend. The historical premiums were adjusted to 2002 (due to the obligations of Crop Insurance Corporation from this year). | • Catastrophic bonds with the parametric trigger, co-financed by the authorities of Mexico and issued by CAT-MEX Ltd. in May 2006.<br>• **Pricing model calibration** is based on estimating the degree of intensity, which describes the strength of an earthquake from two perspectives: (1) of the reinsurance market, including the "sponsor" (authorities of Mexico) and the issuer of reinsurance coverage for risks (Swiss Re); (2) of capital markets (issuer – CAT--MEX Ltd. + investors).<br>• The use of the historical degree of intensity for the comparative analysis whether the reinsurer sells bonds to the investors at a reasonable price.<br>• CAT bonds are a part of the total amount of 450 million of compensation for the earthquake provided by the reinsurer for three years (the total of insurance premiums). Payment in case of losses is determined by confirmation by a leading independent consulting firm developing an assessment of the catastrophic risk. |
| **Payment trigger** | • **Payments (trigger):** the investors lose interest, as well as a part or whole of the principal. The insurance company uses the funds obtained from bonds and accrued interest to cover the losses resulting from the catastrophe.<br>• Payments (no trigger): the investors receive the face value of bonds which includes both the principal and accrued interest, for example LIBOR + risk premium. The difference between the interest on the principal and interest paid to bondholders is a reinsurance cost for the insurance company. | • **Trigger** depends on the frequency and intensity of the earthquake. **Price of a hypothetical bond** is modelled using the so-called modeled index loss trigger, taking into account the physical characteristics of the phenomenon.<br>• Price of a zero-coupon bond increases with an increase in the threshold level (D), on the other hand, it decreases when the expiration time (T) approaches. This is due to the fact that the probability of the trigger increases. It is also expected to receive more coupon payments.<br>• The expected loss from the earthquake is more important to assess catastrophic bonds than the total distribution of losses. |

cont. Table 2

| | | |
|---|---|---|
| **Catastrophe bond pricing** | • **Catastrophe bond pricing** includes: (1) estimation of the probability of a catastrophe and distribution of catastrophic losses, (2) inclusion of the above data and interest rate in the formula calculating the bond value.<br>• **Use of the non-parametric technique** – kernel density estimation in order to obtain the index distribution (percentage deviation from the average yield of the multi-annual period) based on the historical data. Two kernel functions are used to model the distribution of the percentage deviation from the average yield, i.e. Epanechnikov kernel and quartic kernel | **Pricing** uses the so-called compound doubly stochastic Poisson pricing process, according to the methodology previously developed by Baryshnikov et al. (2001). This pricing method is based on several assumptions regarding the stochastic aspect. |
| **Reference to the financial effects (from the perspective of insurance companies)** | The hedge strategy of the insurance company: by minimising the loss ratio for the insurer. | The reinsurance market is based on estimates of the probability of the earthquake lower than that estimated from the historical data. **In the case of catastrophic events on a significant scale and with a significant impact (also on agriculture), it is beneficial to use traditional reinsurance in combination with issuing catastrophic bonds which allows to reduce the costs (when compared to exclusive reinsurance) of providing significant compensation.** |
| **Other comments from the point of view of the possible application of bonds** | Part A of the face value paid to the investors (in the case of triggering the CAT bond mechanism) has a significant impact on the bond price.<br>Higher risk premiums may result in the lower CAT bond prices, all equal. The lower level of triggers leads to the lower CAT bond prices. As a result, the choice of the appropriate level of the trigger is the most important factor associated with issuing catastrophic bonds. | • The bond's rate of return depends on the degree of intensity of earthquakes in the case of the so-called parametric trigger. In the case of the so-called *modeled loss trigger*, there is also the level of aggregated losses.<br>• The availability and quality of historical data provided by the national monitoring authorities have a decisive impact on the degree of accuracy of analyses regarding the assessment of exposure to the catastrophic risk, as well as the possibility to adapt catastrophic bonds to the economic practice. |

Source: Own study based on: (Epperson J.E. 2008, Härdle W.K., Lopez Cabrera B. 2007).

## Conclusions

1. The sustainable development of the agricultural sector is possible thanks to, inter alia, better linking with financial infrastructure. The problem of agriculture, now and in the future, is the high level of the systematic risk, which considerably inhibits the development of the reinsurance market, which is a support for agricultural business insurance. In view of the societal expectations in terms of reducing the scale of the financial interventionism in agriculture[19], desirable will be the promotion of risk management instruments offered by the private sector or forms of public-private partnership. The underdevelopment of financial infrastructure, offering innovative risk management instruments (including catastrophic bonds), may evidence need for regulatory changes (concerning good governance, for example, very accurate legislative provisions on launching disaster payments, suitable criteria for the selection of beneficiaries) to facilitate the introduction of new tools according to the free market principles.
2. Desirable seems to be the approach of the market-enhancing public policy[20]. It is important to take into account the financial instrument, enabling the so-called intertemporal diversification, taking into account the significant differences between the aggregate annual level of insurance premiums and the amount of losses caused by catastrophic events. The central government act as the "activator" of liquidity in the insurance market for farmers, enabling, inter alia, investments of various links of the insurance sector in business systems. The involvement of the state in "activating" the private sector is very desirable, inter alia, due to the pursuit of the more efficient risk allocation mechanism for natural disasters among insurance companies, reinsurers, with the use of geographical "pooling" (aggregating) using market mechanisms[21].

[19] The question about the degree of state interference in the market mechanism is still open. This is evidenced by the discussions of the economists, sociologists, philosophers or political scientists (A. Smith, J.S. Mill, J.J. Rousseau, M. Weber, J.M. Keynes, R.A. Dahl, Ch.E. Lindblom) presenting a solid argument for a given model of cooperation between the state and the economy. Taking into account the typology of the functions of the state apparatus, as indicated by W. Morawski (2011), which identified, inter alia, the state of macroeconomic stabilisation, state intervention may also consist in creating legislative and legal governance, or creating a system of incentives/counter-incentives. This also applies launching so-called "risk management infrastructure" in agriculture, based on free-market instruments.

[20] Proposal to create a reinsurance mechanism at the central level (proposed by Lewis and Murdock in 1996) was based on an assumption that the activities at this level, often supported by the authorities, enable the expansion of the private insurance sector. This is possible by providing certain "institutional investments", which, consequently, allow to trigger the market risk management instruments. Not without significance are here also the activities of the public authorities as part of the so-called disaster policy (mitigation of the consequences of moral hazard, fiscal policy, removing inefficient/inappropriate incentives at the level of central or regional regulatory structures) (Lewis Ch., Murdock K.C. 1999).

[21] Those issues have been discussed in detail in the paper: (Lewis Ch., Murdock K.C. 1999).

3. When assessing the possible use of catastrophic bonds in Polish agriculture, we must stress a specific "inertia" of this sector (when compared to other sections of the economy) in adopting innovative solutions (for example, with regard to organisational methods). But, as noted by A. Kowalski (2013), referring to the thought by A. Woś, the sine qua non condition for enhancing the competitiveness of the Polish agricultural sector will be not only to carry out many structural changes, but above all a series of qualitative changes/transformations, also those regarding management methods. The careful use of the so-called innovative financial instruments should be considered as a beneficial qualitative change being a certain stimulus for further structural changes in the Polish countryside.
4. It should be noted that policy makers in family farms, due to the specificity of these entities, are subject to various heuristics (simplified methods of problem solving)[22]. We should mention here the prospect for the evolution of the Common Agricultural Policy, taking into account the sustainability in integrated terms: social, economic and environmental[23], the departure from which is difficult to imagine. Some kind of stagnation in the development of modern risk transfer instruments in agriculture is not conducive to the competitiveness of the agricultural sector in Poland. Still, *ad hoc* disaster payments are the main instrument of ex post catastrophic risk management, treated also as stabilisation tool for rural prosperity. Changes in international trade in agri-food products (inter alia, related to Transatlantic Trade and Investment Partnership, TTIP, and the ratification of the Association Agreement between the EU and Ukraine) may, however, contribute to the fact that policymakers shall take into account, to a greater extent, the aspect of competitiveness, initially at the level of the production of individual agricultural products (e.g. cereals, oilseeds). Dissemination of the market risk management instruments can support activities to improve this type of competitiveness.
5. The existing, quite poor link between the agricultural sector in Poland and the financial market, as well as the general reluctance of farmers to use financial investments, can be considered as a factor impeding the dissemination of catastrophic bonds. The issues of this kind of debt instruments are possible even at the moderate level of triggers, in terms of the typical sizes

[22] T. Zaleśkiewicz (2011), in discussing the psychological aspects of insurance, stresses, inter alia, (1) heuristics of representativeness – reference to the most "representative" risk factor; (2) availability heuristics – basing opinions on the most available information; (3) effect of freshness – taking into account recent destructive events; (4) effect of affection –strengthening the sentiment associated with the subject of insurance affects the decisions on purchasing an insurance product.

[23] A. Kowalski (2013) underlines that the agricultural policy supporting the sustainable development strategy assumes "reasonable interventionism and state aid, multifunctionality of agriculture itself and rural development, strengthening the local rural and agricultural government, regionalisation and internationalisation"

of losses covered by insurance products (including multiple-peril crop insurance). In addition, the reasonably planned issue (given the number of bonds and specification of contracts) can significantly reduce the variance of the loss ratio determining significantly the economic and financial situation of an insurance company[24].

6. It seems necessary to deepen the network links among research institutes acting for agriculture and its natural environment, as well as the entities determining risk management infrastructure in agriculture. This network, in addition to the obvious task of environmental monitoring, would provide reliable and accurately verified historical data, very important for pricing of financial instruments more or less directly related to catastrophic risk management.

[24] This is evidenced by, inter alia, fairly optimistic results of the studies by J.E. Epperson (2008).

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