# Managing catastrophic risks in agriculture

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**Abstract**

The article addresses the issue of catastrophic risks in agriculture – that is, events with a low probability of occurrence but with a high potential to cause various types of damage. Its primary aim is to provide an overview of these risks and the instruments available for their management. This objective is pursued through answering four research questions. The aim and the questions serve to support the thesis that catastrophic risks can, to a certain extent, be managed if certain conditions are met. Structurally, the article is closest to a monographic-review study. The set of examined partial problems reflects the author's accumulated knowledge gained over more than 25 years of work on risk in agriculture and the food sector. The literature was selected using a combination of manual techniques and a simplified snowballing backward technique. The analysis conducted led to three conclusions: (1) instruments for managing catastrophic risks are already potentially available to farmers, for example in the European Union (EU), but their actual use faces a number of barriers; (2) globally, ad hoc disaster assistance is widely applied, although this could be rationalised through the implementation of holistic catastrophic risk management; (3) the development of the insurance and financial markets, along with their integration and globalisation, is constantly expanding the possibilities for commercially insuring catastrophic risks (without budgetary subsidies).

**Key words**: holistic risk management, catastrophic risks in agriculture, agricultural insurance.

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## Introduction

Catastrophic risks refer to events that are unlikely to occur but have a high potential for negative consequences – personal, social, material and fiscal-financial. If they affect a large number of people and substantial areas, they take on the character of systemic risk. The sources of catastrophic risks include both natural and anthropogenic disasters. Contemporary and future agriculture is confronted with serious threats such as ongoing climate change and its associated increase in extreme weather events, loss of biodiversity, and adverse changes in ecosystems, particularly at so-called tipping points within planetary boundaries[1]. These boundaries relate to nine Earth systems: (1) climate change; (2) biodiversity loss; (3) biogeochemical flows (anthropogenic nitrogen removed from the atmosphere and anthropogenic phosphorus entering the oceans); (4) ocean acidification; (5) land-use change (the percentage of land area converted to cropland); (6) freshwater use; (7) ozone depletion; (8) chemical pollution; (9) the presence of novel entities in the environment[2]. Tipping points are the threshold values of the above Earth system components beyond which sudden, nonlinear and irreversible environmental changes may occur on a continental or global scale, severely hindering sustainable development. Climate change and biodiversity loss are considered the most critical as they are influenced by all other systems. It is estimated that, by the end of 2023, only ozone depletion, chemical pollution, and ocean acidification remained within the established safe boundaries[3].

The increasing risk associated with climate change may lead to mass migrations, which are already destabilising the socio-political and economic systems of many countries. This process is further exacerbated by cyber risks, the spread of disinformation, and the development of artificial intelligence. Geopolitical tensions, new protectionism and trade wars, as well as the growing probability of nuclear weapons proliferation and the lowering of the threshold for their use, are all key sources of

1. E. Bendyk, *Przestrzelona przyszłość*, „Polityka" 2024, No. 49; B. Buchner, *COP 29's climate investment imperative*, „Science" 2024, Vol. 386, No. 6722; Polska Izba Ubezpieczeń, *Klimat rosnących strat. Rola ubezpieczeń w ochronie klimatu i transformacji energetycznej*, Warszawa 2013; World Economic Forum, *The Global Risks Report 2025*, 20th. Edition, 2025; 2024 – first year-exceed-15degc-above-preindustriallevel, https://climate.copernicus.eu, access 11.01.2025.
2. J. Rockström, W. Steffen et al., *Planetary Boundaries: Exploring the Safe Operating Space for Humanity*, "Ecology and Society" 2009, Vol. 14, No. 2.
3. E.J. Hansen, P. Karecha, M. Sato et al., *Global warning has accelerated: Are the United Nations and the public well-informed?*, "Environment: Science and Policy for Sustainable Development" 2025, Vol. 6, No. 1, online issue 3.02.2025; M. Sommer, *Punkt krytyczny dla klimatu*, "Dziennik Gazeta Prawna", No. 25, 6.02.2025; K. Richardson, W. Steffen et al., *Earth beyond six of nine planetary biundries*, "Science Advances" 2023, Vol. 9, No. 37.

real global catastrophic risks. The inevitability of a new pandemic, possibly caused by zoonotic diseases, should also be considered a catastrophic risk. Demand and supply shocks – resulting from the realisation of combinations of catastrophic risks – tend to indirectly and negatively affect agriculture. Conversely, reverse relationships may also occur[4].

In the above context, the primary aim of the article is to present the essence of catastrophic risks and the range of instruments for managing them in agriculture. This aim is to be achieved by answering the following research questions:

1. What is the nature of catastrophic risks and how can they be measured?
2. Can catastrophic risks be insured in the traditional sense?
3. What other instruments, apart from traditional property insurance, can be used to manage catastrophic risks?
4. How should a holistic approach to managing catastrophic risks in agriculture be structured?

The aim and the research questions serve as a means to substantiate the following thesis: the management of catastrophic risks in agriculture is possible, provided that a combination of ex-ante and ex-post instruments can be constructed, tailored each time to the specific place and time as well as to contextual conditions, appropriately addressed to economic and political actors – starting at the micro level (i.e. farms) and extending up to the global level – without simultaneously distorting their incentive structures.

The structure of the article has been adapted to the aim, the questions, and the thesis, while reflecting the logic of risk management. Accordingly, the article begins with the identification of catastrophic risks, their measurement and modelling, and then proceeds to the presentation of instruments and systems for managing them. The author is aware that certain issues have only been signalled, which is an unavoidable cost of any synthetic treatment of a complex problem. Nonetheless, a hidden objective of this paper has primarily been to inspire other researchers to undertake in-depth analyses of specific issues.

4. M.A. Dietrich, J.G. Müller, S.R. Schoenle, *Big news: Climate disaster expectations and business cycle*, "Journal of Economic Behavior and Organization" 2024, Vol. 227; J. Fernández-Villaverde, O. Levintal, *Solution methods for models with rare disasters*, "Quantitative Economics" 2018, Vol. 9; J. Kulawik, *Fundamentalne problemy zarządzania ryzykiem w rolnictwie. Od ryzyka czystego i spekulatywnego do ERM i ryzyka łańcuchów (sieci) żywnościowych*, Warsaw, IERiGŻ PIB, 2022; J. Kulawik (red. nauk.), *Ryzyko katastroficzne i rezyliencja w gospodarce żywnościowej*, not published, Warsaw, IAFE-NRI, 2024.

## Methodological assumptions

In terms of formal classification in Poland (as per the Regulation of the Minister of Science and Higher Education of 22 February 2019), the article resembles a monographic-review study, as it addresses a clearly formulated research problem (managing catastrophic risks in agriculture) and draws upon the most up-to-date literature, while placing it within a historical perspective. A particularly useful benchmark here is the convention adopted by the Journal of Economic Literature (JEL). This journal boasts a very high impact factor (almost 13) and is awarded the maximum 200 points in Poland in the discipline of economics and finance. Articles published in JEL are of a monographic-review character, and each issue is approached from a historical and evolutionary perspective. Accordingly, the publisher of JEL does not object when articles cite publications even from the 19th century or earlier.

Throughout the article, a combination of a modified version of the snowballing backward technique and the manual (traditional) method for reviewing the literature was employed. The essence of snowballing backward lies in constructing a so-called seed set of key titles and then working backwards to incorporate further items[5]. The modification involved the seed set consisting of fifteen English-language and two German-language publications. The author of the article has been monitoring these publications for nearly thirty years and has a thorough familiarity with the material published in them. Additionally, it was assumed that the articles in question would have an impact factor and a minimum of 70 points in the Polish academic classification. This combination, when applied with strong subject-matter expertise, is at least as effective as a systematic review of the literature included in digital databases[6]. As a result, the analysis presented further on is highly up-to-date and addresses the most important issues in this field in a logical manner.

An obvious point of reference for the proposed method of selecting literature is a systematic review. However, despite its unquestionable merits, such a review also

5. C. Wohlin, *Guidelines for Snowballing in Systematic Literature Studies and Replication in Software Engineering, Technical Report EBSE-2007–01*, School of Computer Science and Mathematics, Keele University, 2007.
6. B. Danglot, O. Vera-Perez, Yu 2. et al., *A snowballing literature study on test amplification*, Journal of Systems and Software 2019, Vol. 157; S. Jalali, C. Wohlin, *Systematic Literature Studies: Database Searches vs. Backward Snowballing*, Proceedings International Conference on Evaluation and Assessment in Software Engineering, 2014; Vrije Universiteit Amsterdam, *Snowball method – Research skills – Advanced – Lib-Guides*, https://libguides.vu.nl/c.php, access 7.02.2025; C. Wohlin, M. Kalinowski, K. Romero Felizardo et al., *Successful combination of database search on snowballing for identification of primary studies in systematic literature studies*, "Information and Software Technology" 2022, Vol. 147; K. Wnuk, T. Garropalli, *Knowledge Management in Software Testing: A Systematic Snowball Literature Review*, "e-Informatics Software Engineering Journal" 2018, Vol. 12, No. 1.

has certain drawbacks. The sources used are only approximately up to date, since this method remains labour-intensive and usually requires a team of researchers[7]. This translates into high costs. It is also subject to bias, resulting, for instance, from the way in which search phrases are entered into digital databases[8]. It has a strong bias towards English-language texts and practically excludes the so-called grey literature. Moreover, researchers often do not observe the full rigour of the review process, and some arbitrariness can be observed in their rejection of certain articles[9].

## Essence and context

Catastrophic risks can obviously be derived from the notion of a "catastrophe". Catastrophes (or disasters) are unforeseen events that cause extensive damage and human suffering, the scale of which exceeds local response capabilities and often requires assistance at national or even international level[10]. They may be divided into three broad categories:

1. Natural disasters. These consist of three subcategories: (1) hydrometeorological (floods, storms, and droughts); (2) geophysical (earthquakes, tsunamis, and volcanic eruptions); (3) biological (epidemics and insect plagues).
2. Technological disasters. These are divided into two subgroups: (1) industrial disasters (chemical spills, infrastructure destruction, fires, and radiation); (2) transport-related disasters.
3. Man-made disasters. This category includes two subsets – economic crises manifested in: (1) the collapse of economic growth, hyperinflation, deflation or stagflation, the destruction of the financial system, and severe depreciation of the national currency accompanied by insolvency; (2) broadly understood violence, including acts of terrorism, civil unrest, riots, and even war[11]. The risks associated with these catastrophes should, however, be analysed in close connection with other threats. Table 1 presents an example of such an approach.

7. K.G. Shojenia, M. Samson, *How quickly do systematic reviews go out of date? A survival analysis*, "Annals of Internal Medicine" 2007, Vol. 174, No. 4.
8. I.J. Saldenha, J. Canne, *Adjudication rather than experience of data abstraction matters more in reducing errors in abstracting data in Systematic review*, "Research Synthesis Methods" 2020, Vol. 11, No. 3.
9. B. Danglot, O. Vera-Perez, Yu 2. et al., op. cit.
10. Y. Savada, *The impact of Natural and Manmade Disasters on Household Welfare*, Plenary paper prepared for presentation at the International Association of Agricultural Economists Conference, Gold Coast, Australia, 12–18.08.2006.
11. Ibidem.

**Table 1. Classification of risks**

| Type of risk | Specific, concerning individuals and individual households | Concerning groups of households and local communities | Affecting regions and countries |
|---|---|---|---|
| (micro level) | | (meso level) | (macro level) |
| Natural | – | Rainfall, landslides, volcanic eruptions | Earthquakes, floods, droughts, storms |
| Health-related | Illnesses, injuries, disability, ageing, death | Epidemics | |
| Social | Criminal acts, domestic violence | Terrorism, gang activity | Riots, wars, social unrest |
| Economic | | Unemployment, displacement, crop failure | Food price fluctuations, hyperinflation, banking, financial and currency crises, technological and supply shocks |
| Political | | Social unrest | Collapse of social programmes, uprisings, coups |
| Environmental | | Contamination, displacement, nuclear disasters | |

*Source: Based on: World Development Report 2000/2001, Attacking Poverty, World Bank, Washington D.C. 2001.*

In more in-depth analyses, the natural sources of catastrophic risks are best approached as so-called geohazards[12]. These are natural phenomena that go beyond accepted norms and thus create threats to human safety and life, as well as to economic activity. Although they occur infrequently, they can cause significant losses and damage. In the classification applied in Poland, these hazards encompass the following spheres: atmosphere, hydrosphere, lithosphere, biosphere, and pedosphere (where the focus is on soil erosion). Most geohazards arise from interactions between these spheres, although the strongest links occur between the atmosphere and hydrosphere. The simplest tool for presenting geohazards is mapping. Measures to reduce them include: early warning and crisis management systems; technical and infrastructure solutions; organising dedicated services; protecting natural vegetation and countering deforestation; insurance; media engagement; and public education.

12. Based on: Geografia 24.pl portal, access 9.02.2015.

In insurance, catastrophic risk refers to the danger that many policyholders will submit claims at the same time as a result of certain natural or man-made events[13]. Natural catastrophes – referred to in insurance jargon as "nat cat" – include weather- or geologically-induced events: hurricanes (cyclones, typhoons); earthquakes (sometimes accompanied by tsunamis); hailstorms and tornadoes; floods; fires and snowstorms. Man-made catastrophes, whether accidental or deliberate, include: epidemics and pandemics among humans, animals, or plants; wars and terrorist attacks including cybercrime; displacement and forced migration. Regardless of type, the materialisation of a catastrophic risk always results in sudden, large-scale losses – material, human, and environmental, both direct and indirect[14]. Naturally, this generates a high demand for funds to compensate the resulting damage, affecting both the insurance and reinsurance sectors and public finances, particularly in highly urbanised and densely populated areas. Climate change, which leads to an increasing frequency of extreme weather events, has an ever-greater impact on the rise in catastrophic risk.

Sometimes, catastrophic risks may evolve into systemic risks. The latter first emerged in the banking sector, where it was observed that the financial troubles of even a small bank could lead to a crisis affecting the entire sector. The insurance industry, by contrast, is significantly less exposed to this type of risk. At a global level, we witnessed the materialisation of systemic risk during the Great Depression before the Second World War and the financial and debt crisis of 2008–2009. The Covid-19 pandemic also had the potential to cause a global economic and financial crisis, though this was ultimately averted. A defining characteristic of systemic risk is the phenomenon of contagion or its propagation. Such risk should always be given the highest priority, as it threatens the stability and normal functioning of any system. This recommendation fully applies to today's often globalised and interconnected supply chains, including those relating to food.

## Measurement and modelling

Catastrophic risks present a major challenge to both insurers and reinsurers. While these sectors generally manage independent risks effectively, catastrophic risks are correlated, and if they affect a large population or vast area, they also acquire a systemic nature. As a result, underwriters are unable to rely on diversification as the

13. H. Albrecher, J. Beirlant, L.J. Teugels, *Reinsurance: Actuarial and Statistical Aspects*, Wiley, Hoboken, Chichester, 2017.
14. K. Mitchell-Wallace, M. Jones, J. Hillier et al., *Natural Catastrophe Risk Management and Modelling: A Practitioner's Guide*, Wiley, Chichester, 2017.

primary risk-reduction tool in their portfolios. Additional issues include the difficulty of estimating low probabilities and the lack of repeatability of identical loss events, which makes it impossible to apply the law of large numbers[15]. All of this, naturally, poses threats to the financial stability of an insurance undertaking and may lead to its insolvency. If, despite these challenges, an insurer were to accept catastrophic risk, it would certainly demand very high – effectively prohibitive – premium rates. It is therefore unsurprising that most traditional insurers have various exclusions in place regarding catastrophic risks. This, in turn, complicates the issue of risk and premium valuation, as one must rely on censored and truncated distributions. Fortunately, such distributions are also used for 'normal' risks, where deductibles and liability limits are common. Hence, this issue is of greater relevance to reinsurers than to direct insurers, although close cooperation between the two is essential in the case of catastrophic risks.

Catastrophic risks are modelled using extreme value distributions, of which the four most common are the following[16]:

1. Frechet distribution, with cumulative distribution function:

$$F(x)=\begin{cases} 0 & \text{for } x\leq 0, \\ \exp(-x^{-a}) & \text{for } x>0, \end{cases}$$

where parameter a > 0.

2. Weibull distribution, with cumulative distribution function:

$$F(x)=\begin{cases} \exp[-(-x^{-a})] & \text{for } x\leq 0, \\ 1 & \text{for } x>0, \end{cases}$$

where parameter a > 0.

3. Gumbel distribution, with cumulative distribution function:

$$F(x)=\exp[-\exp(-x)].$$

4. Three-parameter Pareto distribution, with cumulative distribution function:

$$F(x)= 1-\left(\frac{D+\beta}{x+\beta}\right)^{\alpha}, x \geq D,$$

where α, β and D are parameters satisfying the conditions α > 0 and β > –D.

15. P. Kowalczyk, E. Poprawska, W. Ronka-Chmielowiec, *Metody aktuarialne*, Warszawa, Wydawnictwo Naukowe PWN, 2006.
16. Ibidem.

The parameter α indicates the significance of the distribution's 'tail'. As α decreases, the weight of the tail increases. The parameter β describes the left-hand side of the distribution. If x > β, then β does not affect the tail. This means that in some applications β may be omitted. Finally, the parameter D represents the starting point of the indemnity value range.

It follows from the above considerations that, in the case of catastrophic risks, very important information is contained in the tails of distributions. Accordingly, appropriate risk measures must also be applied[17]. Let us now denote by *X* a certain random variable, and by *x* its loss. Let $\delta$ represent the probability level and *E* the expected value operator. The first risk measure for extreme values is the Conditional Tail Expectation (CTE). For a discrete random variable, we have:

$$CTE_\delta(X) = E(X|\ X>x_\delta).$$

In the case of a continuous variable:

$$CTE_\delta(X) = E[X|\ X> VaR_\delta(X)]),$$

where: where $VaR_\delta$ is the Value-at-Risk.

The second extreme risk measure is the Conditional VaR, denoted as $CVaR_\delta(X)$ or simply $CVaR_\delta$. It is calculated as follows:

$$CVaR_\delta(X)=E[X - VaR_\delta(X)|\ X > VaR_\delta(X)].$$

The final standard measure of extreme risk is the Tail Value-at-Risk ($TVaR_\delta(X)$ or $TVaR_\delta$). The corresponding formula takes the following form:

$$\frac{1}{1-\delta}\int_\delta^1 VaR_\xi d\xi,$$

where $\xi = F_x(x)$ is the cumulative distribution function of the variable X.

Essentially, this is a different expression of $CTE_\delta$ (for losses).

The constant development of actuarial science leads to the construction of ever newer risk measures referring to the tails/extremes of loss distributions caused by catastrophic and systemic risks. Without attempting to be exhaustive, the following measures may be mentioned: Conditional Tail Moment (TCM); Haezendonck-Goovaerts Risk Measures (HGRM); Marginal Expected Shortfall (MES); Marginal Moment Excess (MME); Quasi-Linear Mean (QLM); Tail Quasi-Linear Mean (TQLM); and Tail Central

17. R. Kaas, M. Goovaerts, J. Dhaene et al., *Modern Actuarial Risk Theory: Using R*, Berlin, Heidelberg, Springer, 2009; K.Y. Tse, *Nonlife Actuarial Models Theory, Methods and Evaluation*, Cambridge, Cambridge University Press, 2009.

Moment (TCM)[18]. These are primarily used for internal risk management in insurance companies and banks. Additionally, they serve to assess the risk profile of their clients. There are also no obstacles to their application by large firms from the so-called real economy, for instance, when using portfolio theory to optimise the relationship between profitability and risk level. Finally, advanced conditional risk measures are found in scientific research using utility functions (in neoclassical economics and finance) or prospect theory (in behavioural economics and finance)[19].

Based on the book by M.R. Hohl, the issue of modelling catastrophic risks in agriculture will now be addressed[20]. In general, this is an exceptionally difficult task, as it involves biological systems and an enormous variety of losses, their determinants, and risk management instruments and strategies. These model components may change radically over time and space. This results in the exposure of agricultural assets to hazards increasing as production cycles lengthen – losses are typically greatest in their final phases. Most crops, however, have a certain capacity to recover earlier losses. Nevertheless, estimating vulnerability functions in the agricultural sector remains a significant challenge, particularly since these exposures may change radically between successive production cycles. This stems not only from the influence of weather and soil conditions but also from many other factors that are interrelated in complex, still not fully understood ways.

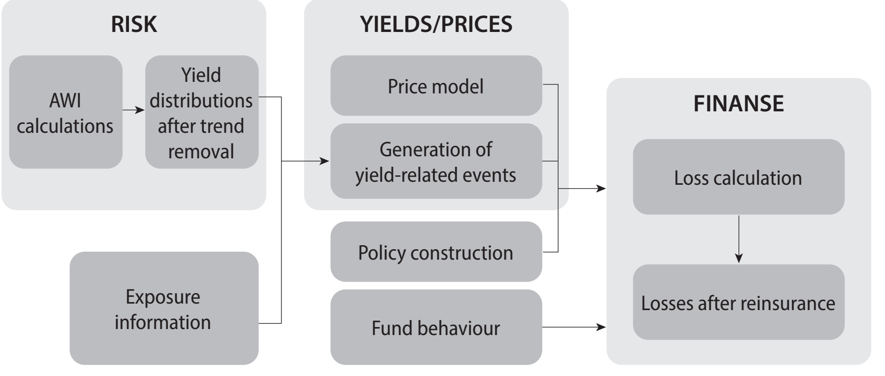
All cat models in agriculture, according to M.R. Hohl, are divided into two groups:

1. Mechanistic models. These are capable of simulating plant growth on a daily basis, and in the case of animals, they may also yield probabilistic analyses. However, they require considerable expertise in calibration. In practice, they are primarily used in research institutions and, in certain countries, in state administration. A certain trend towards open modelling is also observed in this area, which is expected to stimulate greater interest in such models among insurance and reinsurance companies.
2. Probabilistic models. These are usually adaptations of property risk analysis models to the specific characteristics of agriculture. However, they are found only in the major agricultural insurance markets. In the USA and Canada, they are used in crop, livestock and forest insurance, and in India – in relation to crop insurance.

18. J. Lien, T. Shushi, *Asymptotics of the loss-based tail risk measures in the presence of extreme risks*, "European Actuarial Journal" 2024, Vol. 14, No. 1; A. Maček, S. Gheceva, M. Murg, *Impact of natural disaster on the value of (Re)Insurance Companies*, "German Journal of Risk and Insurance" 2023, Vol. 112, No. 4.
19. T. Mao, J. Hu, H. Liu, *The average risk sharing problem under risk measure and expected utility theory*, "Insurance: Mathematics and Economics" 2018, Vol. 83(C); Q. Tang, Y. Yang, *Worst-case moment under partial ambiguity*, ASTIN Bulletin: "The Journal of the IAA" 2023, Vol. 53, No. 2.
20. M.R. Hohl, *Agricultural Risk Transfer. From Insurance to Reinsurance to Capital Market*, Wiley, Chichester, 2019.

The first fully mature cat model in agriculture was created by the American company AIR Worldwide Corporation from Boston, which is a global leader in this business area[21]. The model relates to crop insurance and was calibrated on the basis of 2007 data. The model has a modular structure, and its construction is presented in Figure 1.

**Figure 1. Architecture of a cat model for agriculture**




*Source: Based on: O. Vergara, G. Zuba, T. Doggett et al., Modelling the potential impact of catastrophic weather crop insurance industry portfolio losses, "American Journal of Agricultural Economics" 2008, Vol. 90, No. 5.*

## Insurability and alternative risk transfer

It is often claimed that there are no absolute limits to the insurability of individual risks, as this essentially depends on the price of the service accepted by both parties – namely, the level of premium and insurance rate[22]. However, this is an overly simplistic view, as in practice the following factors are also taken into account:

1) the decision-making context of the entity considering the purchase of a policy, its objectives and broader operational environment, in particular its exposure to aggregate risk and its components, as well as the net balance of benefits and drawbacks of obtaining coverage;

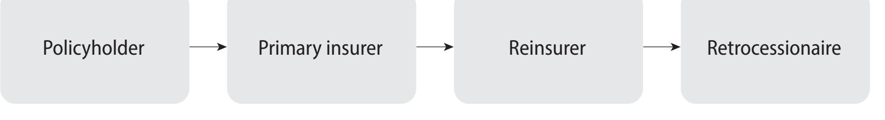
21. O. Vergara, G. Zuba, T. Doggett et al., *Modelling the potential impact of catastrophic weather crop insurance industry portfolio losses*, "American Journal of Agricultural Economics" 2008, Vol. 90, No. 5.
22. H.K. Borch, *Economics of Insurance*, North-Holland, Amsterdam-London-New York-Tokyo, 1992; W. Kartern, M. Nell, A. Richter et al., *Risiko und Versicherungstechnik. Eine ökonomische Einführung*, Wiesbaden, Springer Gabler, 2018.

2) the insurer's overall risk profile, the state of its portfolio into which the transferred risk would be included, its service and capital potential, and its technical and insurance proficiency, particularly in terms of managing its own risk, as well as access to the co- and reinsurance markets, retrocession, and alternative risk transfer/financing instruments;
3) the characteristics of the risk (i.e. a specific random variable) that is to be insured, in particular the following features:
   – randomness of the loss distribution;
   – the ability to estimate the loss distribution;
   – clarity of the loss distribution;
   – independence of the aforementioned distribution;
   – features of the distribution of loss severity[23].

Catastrophic risks only partially meet these five technical-insurance criteria. The analysis by Louaas and Picard – which is highly advanced in formal terms and conceptually refined – shows that in the broadest sense even catastrophic risks can be insurable, provided the incompleteness and imperfections of financial markets are reduced, and the adverse effects of government intervention in the field of property insurance are minimised. This would represent the optimal, so-called first-best solution. However, the implementation of public-private partnerships and mandatory insurance against catastrophic risks constitutes a second-best policy[24].

Co- and reinsurance contracts offer significant possibilities for dealing with catastrophic risks within the insurance sector. Their essence can be illustrated as follows:

**Figure 2. Co- and reinsurance contracts**




*Source: Based on: S. Pohl, J. Iranya, The ABC of Reinsurance, Karlsruhe, VVW, 2018.*

Under the Act of 5 July 2005, within the Polish system of subsidised crop and livestock insurance, the risk of drought may be subject to reinsurance. For completeness, it should be added that protection against catastrophic risks may also be provided within the framework of supply chain finance (SCF). In general, this is an innovative

23. E.G. Rejda, J.M. McNamara, *Principles of Risk Management and Insurance*, London, New York, Pearson, 2017.
24. A. Louaas, P. Picard, *Optimal insurance coverage of low-probability catastrophic risk*, "The Geneva Risk and Insurance Review" 2021, Vol. 46, No. 1.

and cooperative approach to delivering credit and financial and insurance services to small and medium-sized enterprises by converting incomplete assets (raw materials, inventories, and receivables) into cash. The development of this concept only gained real momentum in the second decade of this century[25].

The accumulation of risk and catastrophic risk for individual insurers and reinsurers, or even for the entire insurance sector, can pose a serious threat if it exceeds their so-called acceptance capacity. At this point, alternative risk transfer (ART) methods may prove useful. In Poland, however, these are classified as financial reinsurance[26]. They emerged in the United States in the 1990s. These include: captive insurance companies; solutions from the insurance market (multi-line/multi-year programmes, integrated and limited-risk programmes); and financial market instruments (bonds, derivatives, swaps, insurance-linked securities «ILS», and contingent capital)[27].

## Index-based crop insurance (contracts)

So far, conventional insurance of farmers' property has dominated worldwide – insurance in which, after paying an appropriate premium, some form of compensation can be expected in the future. As is well known, such insurance suffers from problems of adverse selection, moral hazard and systemic risk. Consequently, there are difficulties in dispersing and diversifying the negative effects of random events that affect a large number of farmers in a given region simultaneously. These problems can, in principle, be mitigated by taking out co- and reinsurance contracts, but this ultimately results in higher insurance premiums offered to farmers. However, there is another answer to the aforementioned weaknesses of conventional insurance – the development of index-based contracts.

Index-based insurance began to emerge in the last decade of the previous century. Its core principle is that any compensation is based on the behaviour of a specific category or a variable closely correlated with it, referred to as the "index". This category – or more precisely, the random variable or a combination of such variables – must be easily and reliably observable and strongly correlated with the actual losses, while at the same time remaining outside the influence of the insured person. The indices most commonly used are variables related to weather (precipitation and temperature) and soil fertility. Other

25. Kulawik J. (red.), *Luka finansowa w rolnictwie a instrumenty finansowe. Studium przypadku na podstawie PROW 2023–2027*, Warszawa, IERiGŻ PIB, 2021.
26. Iwanicz-Drozdowska M. (red. nauk.), *Ubezpieczenia*, Warszawa, Polskie Wydawnictwo Ekonomiczne, 2018.
27. H. Gondring, V*ersicherungswirtschaft. Handbuch für Studium und Prasis*, München, Vahlen, 2015. ART is discussed in more detail in: J. Kulawik, *Teoretyczne podstawy ubezpieczeń szkód majątkowych w rolnictwie*, Warszawa, IERiGŻ PIB, 2020.

possible indices include: yields from a specific region, regional livestock mortality rates, river water levels, the El Niño phenomenon, and satellite images of crop vegetation. Indices can also be constructed on the basis of: spot and futures prices, agricultural product values, direct surpluses, and input costs (e.g. energy and mineral fertilisers).

The evaluation of index-based insurance – clearly in comparison with conventional insurance – is complex. One of its strengths is, at least theoretically, the absence of moral hazard, since the farmer cannot influence the value of the indices. The public availability of these indices significantly reduces the scope for adverse selection. Furthermore, the standardisation of contracts substantially lowers administrative and transaction costs. Overall, the reduced need for specific information and the transparency of the data-gathering processes make index-based insurance easier to reinsure. All in all, these types of insurance may be cheaper than conventional ones, which could encourage uptake by poorer farmers. On the other hand, however, there is basis risk – the fundamental weakness of index contracts. This refers to the lack of a guarantee that even substantial individual losses will automatically be compensated, if they are not sufficiently closely correlated with the value of the index. The risk of receiving no compensation increases when the microclimate is diverse and unstable over time.

Table 2 presents the main differences between traditional and index-based insurance.

**Table 2. Advantages (+) and disadvantages (–) of traditional and index-based insurance**

| **Traditional insurance** | | **Index-based insurance** | |
|---|---|---|---|
| **Single-risk** | Multi-risk | Group-based | Weather-based |
| **+ Conditional compensation payments** | + Conditional compensation payments | – Residual risk remains with the farmer | – Residual risk remains with the farmer |
| **– Protection against only certain risks** | + Protection against a defined list of risks | + Protection against a defined list of risks | + Protection against a defined list of risks |
| **+/– Moderate administrative and regulatory costs** | – Very high administrative and regulatory costs | + Low administrative and regulatory costs | + Very low administrative and regulatory costs |
| **+/– Moderate moral hazard risk** | – Very high moral hazard intensity | +/– Moderate moral hazard risk | + Complete absence of moral hazard |

*Source: Based on: N. Hirschauer, O. Mußhoff, Risikomanagementinstrumente im Vergleich: Sollte man landwirtschaftliche Ernteversicherungen subventionieren? – Gute alte Argumente in einem neuen Streit [in:] E. Berg, M. Hartmann, T. Heckelei et al., Risiken in der Agrar- und Ernährungswirtschaft und ihre Bewältigung. Schriften der Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V., Band 44, Münster-Hiltrup, Landwirtschaftsverlag, 2009.*

Since 2021, the National Agricultural Support Centre (KOWR) has been implementing a project entitled "Satellite Monitoring System for Agricultural Crops" (S2MUR), the aims of which include, inter alia, supporting farmers' decision-making and providing information on yields and crop damage. The design and construction of S2MUR were commissioned to the Institute of Soil Science and Plant Cultivation – State Research Institute in Puławy (IUNG PIB) on 30 July 2023. From the officially available information published on the websites of the above institution and the author's personal contacts, it is clear that the project is experiencing delays and it remains uncertain when the system will be implemented. If it is implemented, part of the technical infrastructure necessary for launching work on index-based insurance in Poland will be established. Naturally, S2MUR would also need to be integrated with the network of meteorological stations of the Institute of Meteorology and Water Management – National Research Institute (IMGW PIB) and the stations owned by larger agricultural holdings.

In 2022, under the project entitled "Agricultural insurance in holistic risk management in agriculture oriented towards sustainability, the implementation of innovation and technology, and climate change mitigation" (UBROL), in which the Institute of Agricultural and Food Economics – National Research Institute (IERiGŻ PIB) acted as the substantive leader, a study was conducted on the feasibility of introducing into Polish agriculture an index-based scheme to compensate for drought-related losses[28]. The study covered 453 farms from across Poland. Three crops were analysed: winter wheat, oilseed rape, and sugar beet. It was found that the index-based product could be purchased by farmers, particularly those engaged in arable farming and diversified production. However, actual demand may be significantly lower, as index-based insurance must be reliable, safe, and intuitively understandable. It is likely that a separate act would be required, or at least a thorough amendment to the existing legislation.

## EU instruments for stabilising agricultural incomes

This refers to the income stabilisation tool (IST). As early as the Rural Development Programme 2014–2020 (RDP 2014–2020), the European Commission offered Member States the above instrument as a means of addressing catastrophic risks, the materialisation of which ultimately results in a decline in agricultural incomes. The

28. M. Kaczała, K. Łyskawa, *Konstrukcja ubezpieczenia indeksowego suszy w zakresie wybranych upraw i jego akceptacja przez rolników w Polsce* [in:] *Weryfikacja praktyczna proponowanych produktów ubezpieczeniowych i skonstruowanie systemu holistycznego zarządzania ryzykiem (pilotaż)*, red. nauk. M. Soliwoda, Warszawa, IERiGŻ PIB, 2022.

inspiration came from solutions adopted in Canada and the United States. At the same time, the European Commission envisaged that farmers' mutual funds could also be subsidised to manage the IST or, in other words, act as its operators.

The starting point for the construction of the IST must be a precisely defined and measured category of agricultural income. R. Finger et al., in their work, refer to the convention proposed in 2011 by the European Commission[29]. Income, according to that definition, is the difference between the farm's revenues and the sum of fixed and variable costs, excluding remuneration for family labour. A farmer may receive compensation if, in a given year, their income falls by more than 30% compared to the Olympic average, which excludes the extreme values from the five preceding years. This parameter is denoted as $\overline{I}_0$. In other words, it is the expected income. Hence, we obtain the reference income $I_R$, equal to $0{,}7\overline{I}_0$, that is, the threshold activating the compensation payment. What remains is to measure the actual income $I_i$ in the given year. We may now present the general rule for the compensation payment:

$$compensation = \begin{Bmatrix} 0 \quad , & if \quad I_i \geq I_R \\ 0.7(\overline{I}_0 - I_i), & if \quad I_i < I_R . \end{Bmatrix}.$$

On 13 December 2017, however, the EU adopted the Omnibus Regulation (Reg. 8314/2017), which introduced two facilitations:

1) the damage threshold above which compensation becomes payable was lowered from 30% to 20%;
2) in sector-specific ISTs, it would be possible to monitor the evolution of relevant indices instead of declines in income on individual farms.

These changes took effect at the beginning of 2018. Unfortunately, it remains unresolved whether the lowered threshold will continue to be recognised by the World Trade Organization (WTO) as compliant with the criteria of the so-called green box.

Several EU countries (France, Spain, Romania, Hungary, Italy) planned to implement the IST. However, only Italy succeeded. R. Rippo and S. Cerroni were the first pair of researchers to examine the determinants of participation in the IST by apple producers from the Autonomous Province of Trento-South Tyrol[30]. The instrument was introduced at the beginning of 2019. The entire three-year study period covered 2019–2022. A total of 3,268 farms participated, and the sample took the form of a balanced panel. R. Rippo and S. Cerroni applied a combination of two research methods:

29. N. El Benni, R. Finger, P.M.M. Meuwissen, *Potential effects of the income stabilisation tool (IST) in Swiss agriculture*, "European Review of Agricultural Economics" 2016, Vol. 43, No. 3.
30. R. Rippo, S. Cerroni, *Farmers participation in the Income Stabilisation Tool: Evidence from the apple sector in Italy*, "Journal of Agricultural Economics" 2022, Vol. 74, No. 1.

the Unified Theory of Acceptance and Use of Technology (UTAUT) by V. Venkatesh et al. from 2003 and the logit regression model following the Mundlak and Chamberlain procedure, also known as the pseudo-fixed effects model. UTAUT is, in essence, an integration of as many as eight specific sociological, psychological, and cognitive theories. In general, this theory assumes that individuals' behaviour is a derivative of their expectations regarding future outcomes, the effort associated with achieving them, social influence, and facilitating conditions. However, these constructs are not directly observable and thus are considered latent variables. They therefore had to be described using certain proxy characteristics. Among the remaining explanatory variables were directly observable variables: the age and gender of the farm manager; the legal status of the farm (natural person or company); the region; the use of other risk management instruments; parameters of the IST itself; and aspects relating to the mutual fund. The model was estimated using the aforementioned logit model, the formal specification of which consisted of three equations.

Following the relevant regression calculations, it was found that participation in IST was encouraged by the following factors: greater specialisation of production, which led to higher exposure to risks; previous positive experiences with participation in mutual funds; and certain self-protection and self-insurance instruments. The results obtained have a broader relevance for entire food sectors. Put simply: since IST was conceived as a tool for addressing catastrophic and systemic risks within agriculture itself, its positive impact in this sector also generates a beneficial network externality in the form of enhanced resilience across the entire food sector. Among the favourable conditions for achieving such outcomes, top priority must be given to high levels of social capital, trust, and a readiness to engage in cooperative action and behaviour – for instance, through membership in various forms of cooperatives. Unfortunately, Poland is not among the countries that exhibit these characteristics.

In 2022, the Institute of Agricultural and Food Economics – National Research Institute (IERiGŻ PIB) carried out a study aimed at proposing the principles for implementing IST in Polish agriculture[31]. The basis for calculating farmers' premiums and the burden on the state budget consisted of data from the Polish Farm Accountancy Data Network (FADN). Overall, it was found that the most effective solution would be to establish sectoral mutual funds. However, to date, the proposed IST has not generated any interest on the part of public administration or agricultural organisations.

31. M. Soliwoda, J. Pawłowska-Tyszko, M. Juchniewicz et al., *Instrument stabilizacji dochodów* [in:] *Weryfikacja praktyczna proponowanych produktów ubezpieczeniowych i skonstruowanie systemu holistycznego zarządzania ryzykiem (pilotaż)*, red. nauk. Michał Soliwoda, Warszawa, IERiGŻ PIB, 2022.

## Crisis management and insurance against loss of profit/income

Crisis management comprises two classes of actions:

1) preventive measures,
2) crisis mitigation[32].

The first are undertaken before a crisis occurs, while the second are applied after it has broken out. At times, crisis management also encompasses legal claims and the incurrence or causation of damage. Every organisation must also be prepared to respond to a deliberately provoked crisis. In the age of the Internet and social media, a crisis may emerge as soon as a particular event is picked up by the media.

Quite naturally, prevention serves two purposes: to avoid a crisis and to reduce its negative consequences. This requires careful planning and the selection of appropriate tools. In larger organisations, this may be the responsibility of dedicated crisis teams. In smaller ones, such as family businesses and farms, these tasks fall to the manager, who is usually also the owner. Crisis response essentially means controlling the situation, minimising losses, and simultaneously learning lessons to improve and update future preventive actions.

A crisis may also be understood as the occurrence of an event with a low probability but severe consequences[33]. Farmers in the EU are often not particularly aware of the potential materialisation of such situations, as they benefit from significant direct and indirect budgetary support as well as ad hoc disaster assistance. They tend to be more concerned about frequent but less harmful losses, which results in limited interest in insurance products. Moreover, in most EU countries, agriculture already plays a limited economic role, meaning that a crisis in this sector would primarily result in rising food prices. The issue becomes significantly more complex when a crisis affects the food supply chain, especially if it poses a threat to public health or is caused by a pandemic, such as Covid-19, which in extreme circumstances may lead to its collapse. Crises in agriculture in developing countries generally have serious economic-fiscal and socio-political consequences, at both regional and global levels (e.g. the so-called Arab Spring).

32. T. Rohlfs, *Risikomanagement im Versicherungsunternehemen: Identifizierung, Bewertung und Steuerung*, Karlsruhe, Versicherungswirtschaft, 2018; M. Siedl, K. Regeling, *Schaden – und Krisenmanagement* [in:] *Betriebliches Risikomanagement und Industrieversicherung. Erfolgreiche Unternehmensteuerung durch ein effektives Risiko-und versicherungsmanagement*, Hrsg. A. Mahnte, T. Rohlfs, Wiesbaden, Springer Gabler, 2020.
33. M.P.M. Meuwissen, M.P.A.M. van Asseldonk, M.B.R. Huirne, *Coping with Crisis Risk in European Agriculture*, “Eurochoices” 2006, Vol. 5.

As early as March 2005, the European Commission put forward the following three proposals as the basis for a risk and crisis management system in EU agriculture:

1) co-financing of farmers' insurance premiums paid to cover natural risks;
2) support for mutual funds;
3) provision of basic protection against crisis-induced income declines[34].

Subsequently, various other actions and instruments were introduced within the framework of the common organisation of agricultural markets (CMO). These include, in particular, public intervention, private storage of products, and extraordinary measures applied in crisis situations. However, the budget for such actions is not particularly large, and their activation requires a series of administrative procedures.

Business interruption insurance (BII) is explicitly intended to cover losses resulting from catastrophic events[35]. It may also be used to finance the reconstruction of damaged or lost assets. Importantly, BII is, by definition, designed to compensate for the benefits that could have been realised had the catastrophe not occurred at all. This constitutes a fundamental distinction from conventional property insurance. BII may be offered as an additional component to traditional insurance policies. In such cases, it may form part of a business owner's policy (BOP). However, it is also available as a standalone product. Regardless of policy type, BII may be used to compensate losses such as foregone profits/income, fixed costs, temporary relocation costs, commissions and staff training expenses, extra expenditures, and losses caused by administrative action or, for example, the imposition of a curfew.

BII is generally a type of product available under industrial insurance. Historically, it evolved from fire insurance, which was already available by the end of the seventeenth century[36]. Efforts have been made to implement it in agriculture in Germany and the Netherlands, particularly for managing risks in livestock production, protected horticulture, and aquaculture. However, no spectacular successes have been recorded in this area, as considerable controversy remains over the issue of compensating indirect losses by insurers[37].

The increasing risks associated with climate change and the extreme weather and geopolitical events accompanying it, the emergence of new forms of neo-protectionism in international trade, the real possibility of another pandemic, the recurring outbreaks

34. C. Cafiero, F. Capitanio, A. Cioffi et al., *Risk and Crisis Management in the Reformed European Agricultural Policy*, "Canadian Journal of Agricultural Economics" 2007, Vol. 55.
35. E.G. Rejda, J.M. McNamara, op. cit.
36. R. Keil, *Betriebsunterbrechungsversicherung. Ursachen, Wirkungen und Lösungen*, Karlsruhe, VVW, 2019.
37. U. Hartung, *Extremwetterereignisse in der Landwirtschaft: Risikomanagement im Bundesländervergleich*, "Berichte über Landwirtschaft" 2020, Vol. 98, No. 2; O. Melyukhina, W. Yoon, *Producer incentives in livestock disease management: a synthesis of conceptual and empirical studies. Draft Report – OECD Conference Centre*, Paris 2017.

of disease among livestock with the potential for zoonotic transmission (such as avian influenza to humans), as well as the development of artificial intelligence, are among the key factors potentially increasing demand for BII products[38]. This trend is reinforced by the fact that BII is designed as an ex-ante instrument for managing catastrophic risk, whereas public disaster assistance is ex-post in nature and only partially compensates for losses. According to research by the National Association of Insurance Commissioners (NAIC), it is estimated that only 30–40% of small and medium-sized enterprises worldwide have made use of such protection[39]. No such studies have been carried out in Poland, although it may be assumed that the penetration rate is likely even lower. In Polish agriculture itself, according to unofficial information from insurers offering such products, BII is only occasionally encountered among poultry and pig producers. These products are considered too expensive. Internationally, it is further noted that the actual scope of coverage provided is also often inadequate. In general, during the Covid-19 pandemic it became clear that insurers were unwilling to cover losses resulting from the outbreak[40].

The demand for BII may increase with improvements in financial knowledge and competence among economic operators[41]. This has been empirically demonstrated by O. Ricco and G. Santilli, who analysed 1,908 small non-financial Italian enterprises, drawing on, among other sources, the 2021 methodology of the Organisation for Economic Co-operation and Development (OECD) for measuring financial literacy and competence[42]. The source material was collected via a survey conducted between March and May 2021. Upon applying a two-stage logit regression, it was found that such knowledge and competence significantly increased the likelihood of purchasing BII by more than 24%. Interestingly, the binary variable /agricultural, forestry and fisheries-related activity' had a similar effect, albeit with much weaker intensity (an increase in probability of just under 6%).

38. S.L. Schwarz, *Insuring the „Uninsurable": Catastrophe bonds, pandemics, and risk securitization*, "Washington University Law Review" 2021, Vol. 90; U. Stahl, *Distant relations: business interruption insurance and business closure insurance*, "The Geneva Papers on Risk and Insurance – Issue and Practice" 2023, Vol. 48, No. 3.
39. NAIC (National Association of Insurance Commissioners), *Business interruption policies (BOP)*, 2022, https://policies-boop, access 15.01.2025.
40. European Union, *EIOPA Staff paper on measures to improve the insurability of business interruption risk in light of pandemics*, 2021, https://doi.org/10.2854/293053, access 15.01.2025; H. Gründl, D. Guxha, A. Karatseva et al., *Insurability of pandemic risks*, "Journal of Risk and Insurance" 2021, Vol. 88, No. 4.
41. P. Finaldi-Russo, L. Galotto, C. Rampazzi, *The Financial Literacy of Micro-entrepreneurs: Evidence from Italy*, "Bank of Italy Occasional Paper" 2022, No. 727.
42. O. Ricci, G. Santilli, *Exploring the link between financial literacy and business interruption insurance: evidence from Italian micro-enterprises*, "The Geneva Papers on Risk and Insurance – Issues and Practice" 2024, Vol. 49, No. 4.

## Transfer of catastrophic risks to the macroeconomic sphere

Catastrophic risks, when materialised in agriculture, propagate through their integration into sector-specific food chains and networks, ultimately affecting the entire national economy and society. There is also a reverse transmission of such risk from the broader environment into the agricultural sector. In macroeconomics, these reciprocal effects are referred to as "shocks" or "disturbances", which may be either supply-side or demand-side in nature. Only selected aspects of these two-way relationships will be signalled below.

The adverse consequences of the materialisation of catastrophic risks in agriculture also have macroeconomic repercussions. These are most commonly modelled using New Keynesian frameworks[43]. Such models generally comprise three core components:

1. Households, which purchase specific bundles of consumption and investment goods within defined budgetary constraints. These models incorporate the probability of asset losses while simultaneously assuming that households seek to maximise a periodic utility function.
2. Firms, which compete under monopolistic competition on the basis of specified production functions. When firms incur losses, their productivity declines, which in turn affects their objective-maximising behaviour.
3. Labour market equilibrium and monetary policy, with the latter modelled using a feedback rule governing interest rate changes and their effects on inflation, investment, output, the output gap, and the natural interest rate.

Losses caused by the materialisation of catastrophic risk are typically modelled as negative demand shocks. This implies a leftward shift of the aggregate demand curve, leading to a decline in GDP below the economy's potential, a fall in price levels and interest rates, and possibly even a short-term decrease in supply. Investment expenditure may, however, increase[44].

The mechanism by which expectations form in relation to the occurrence of such demand shocks is particularly noteworthy. People learn about catastrophic risks from various sources and subsequently estimate their subjective probability of occurrence and the expected size of potential losses. Because such risks are, by definition, rare, they are often assigned a high subjective probability, even though their objective likelihood, again, by definition, is low. Clear differences in the perception of such risks are

43. M.A. Dietrich, J.G. Müller, S.R. Schoenle, op. cit.; J. Fernández-Villaverde, O. Levintal, op. cit.
44. Ibidem.

observable depending on respondents' levels of economic knowledge and education. In general, better-educated individuals assign lower subjective probabilities[45]. In anticipation of catastrophic losses or after such losses have materialised, individuals employ various coping strategies. These may include: increasing precautionary savings; undertaking preventive investments; or relocating to another area. It is often observed that following a catastrophe, demand for property and life insurance increases[46]. Unfortunately, this phenomenon tends not to be long-lasting.

In the context of the general positioning of catastrophic risks, the OECD's perspective is of particular interest, as it introduced the concept of destabilising risks[47]. These are events that may lead to highly negative and relatively persistent consequences in such areas as public health, human well-being, the economy, the natural environment, the provision of public goods and services, and the socio-political situation.

Building on this approach, H.B. van Voss and J. Helsloot additionally proposed introducing two types of destabilising risks: far-future risks and low-chance risks[48]. Examples of the first group include the degradation of nature, loss of biodiversity, and climate change. The primary strategy for dealing with such risks is the implementation of public investments that, in the future, would minimise the negative effects of their materialisation. The authors classified volcanic eruptions, pandemics, and nuclear disasters as belonging to the second category. The main instruments for mitigating such threats should be various types of insurance contracts secured through co-insurance, reinsurance, retrocession, and alternative risk transfer (ART). The construction of social safety nets is also essential.

## Disaster relief

This is a commonly used ex-post instrument for managing the negative consequences of catastrophic risks. The wide geographical scope of the effects of catastrophic risks when they materialise, their correlation (thus taking on a systemic nature), and the limited possibilities of transferring them to private insurers are two very general reasons for governmental involvement in managing such risks. These justifications merit

45. M.A. Dietrich, J.G. Müller, S.R. Schoenle, op. cit., 2024.
46. S.G. Fier, J.M. Carson, *Catastrophes and the demand for life insurance*, "Journal of Insurance Issues" 2015, Vol. 38, No. 2; J. Gallagher, *Learning about an infrequent event: Evidence from flood insurance take-up in the United States*, "American Economic Journal: Applied Economics" 2023, *Mitigation disaster risks in the age of climate change*, "Econometrica" 2023, Vol. 95, No 5.
47. OECD, *National risk assessment: A cross-country perspective*, Paris 2018.
48. H.B. Van Voss, J. Helsloot, *How states deal with long-term destabilizing risks*, "Journal of Risk Research" 2023, Vol. 26, No. 10.

closer examination. D.J. Cummins argues that the mere fact that insurance protection available on the market does not fully cover catastrophic losses already constitutes sufficient grounds for state intervention[49]. However, it is worth noting that this is a natural situation – insurers typically require insured parties to bear part of the losses, and such contracts may also be optimal. Another justification lies in the fact that only governments have the capacity to spread risk across almost all citizens, thanks to their fiscal authority[50]. Unfortunately, the individual burdens or benefits derived from this are generally small. In other words, it is public institutions that effectively assume the risk and serve as reinsurers of last resort. This term originates from banking and finance and refers to a situation in which, during a systemic crisis, when interbank credit is no longer accessible, the state steps in to provide liquidity. By analogy, we may assume that when a catastrophe and/or natural disaster occurs and people and businesses run out of cash, the state will step in to supply it. Another argument is based on well-documented empirical evidence that people consistently underestimate risk and thus opt for too low a level of insurance cover; ergo, they are underinsured. A further premise is adverse selection.

There are several reasons that should prompt at least scepticism regarding the rationale for governments providing disaster assistance. Perhaps the most important objection is that it gives rise to the so-called crowding-out effect. This occurs in two forms: it weakens incentives for the development of the private insurance sector, and it demotivates beneficiaries of public support from maintaining adequate self-insurance (measures that reduce the magnitude of losses) and self-protection (measures that reduce the likelihood of losses occurring)[51]. These risk management strategies are closely linked to moral hazard, both in its ex-ante and ex-post forms[52]. The former refers to the deliberate selection of riskier actions prior to entering into an insurance contract. The latter refers to reduced effort after purchasing a policy in respect of self-insurance and self-protection activities. Ideally, budgetary support should prioritise the development of catastrophic risk insurance and ART (Alternative Risk Transfer).

Unfortunately, in practice, for political reasons, governments are more inclined to offer disaster relief, which may inhibit the development of market-based instruments for managing catastrophic risks and undermine incentives for self-protection and self-insurance.

49. D.J. Cummins, D. Barrieu, *Innovations in Insurance Markets: Hybrid and Securitized Risk Transfer* [in:] *Handbook of Insurance*, ed. G. Dionne, Second Edition, New York, Heidelberg, London, Springer, 2013.
50. K.A. Froot, *The market for catastrophe risk: a clinical examination*, "Journal of Financial Economics" 2001, Vol. 60, No. 2–3.
51. D.J. Cummins, D. Barrieu, op. cit.
52. L. Kaplow, *Incentives and government relief for risk*, "Journal of Risk and Uncertainty" 1991, Vol. 4, No. 2; G.L. Priest, *The government, the market, and the problem of catastrophic loss*, "Journal of Risk and Uncertainty" 1996, Vol. 12, No. 2–3.

Assessing the premises, effectiveness and efficiency of disaster relief is not straightforward. It is certainly a form of free assistance for beneficiaries, but a costly one for taxpayers. These benefits, however, are less certain and comprehensive, and less complete in terms of loss coverage, than insurance. The availability of disaster relief weakens the motivation of asset owners to reduce their exposure to hazards and to make greater efforts to mitigate risks. While catastrophic losses cannot be diversified among the insured, governments are in a position to diversify them over time.

## Holistic management of catastrophic risks

Holistic or, in other words, integrated management of catastrophic risks in agriculture should be considered both at the level of individual farms and the entire agricultural sector. Since many catastrophic risks are transnational in nature, their management should be pursued through international cooperation between states.

It is highly desirable for market-oriented farms to have at least a rudimentary crisis management framework in place. However, this is a separate issue that deserves dedicated treatment. The situation is further complicated by the fact that crisis management only became the subject of broader scholarly interest after the Covid-19 pandemic. Therefore, what follows is a very general outline. Theoretically speaking, crisis management can be anchored in concepts such as the dynamics of power shifts, resource dependency, inter-actor relations, or in original and new institutional economics[53]. A specific application of the latter may be found in the constrained rural entrepreneurship (CRE) approach, which focuses on identifying the barriers that hinder farmers from developing and implementing effective anti-crisis strategies[54]. An extension of this is the constrained institutional contexts (CIC) approach, which also takes into account conditions affecting agricultural competitiveness and the social aspects of the farming and rural environment[55].

53. P. Gittins, G. McElwee, *Constrained entrepreneurship: upland farmer response to the socio-political challenges in England's beef and sheep sector*, "Journal of Rural Studies" 2023, Vol. 104.
54. D. Refai, N. Elkafraui, P. Gittins, *Creating a sustainable ripple in rural entrepreneurship – the case of Deserttulip in resource-constrained rural Jordan*, "Journal of Entrepreneurial Behavior" 2024, Vol. 30, No. 1; M. De Rosa, A. Castelli, N. Bartoli et al., *Sustainable public procurement and constrained agricultural*, "Journal of Rural Studies" 2023, "AIMS Agriculture and Food" 2023, Vol. 8, No. 2.
55. P. Gittins, G. McElwee, J. Lever, *Constrained entrepreneurship in UK agriculture: A Weberian analysis*, "Journal of Rural Studies" 2022, Vol. 95; P. Gittins, G. McElwee, *Constrained entrepreneurship: upland farmer response to the socio-political challenges in England's beef and sheep sector*, "Journal of Rural Studies" 2023, Vol. 104.

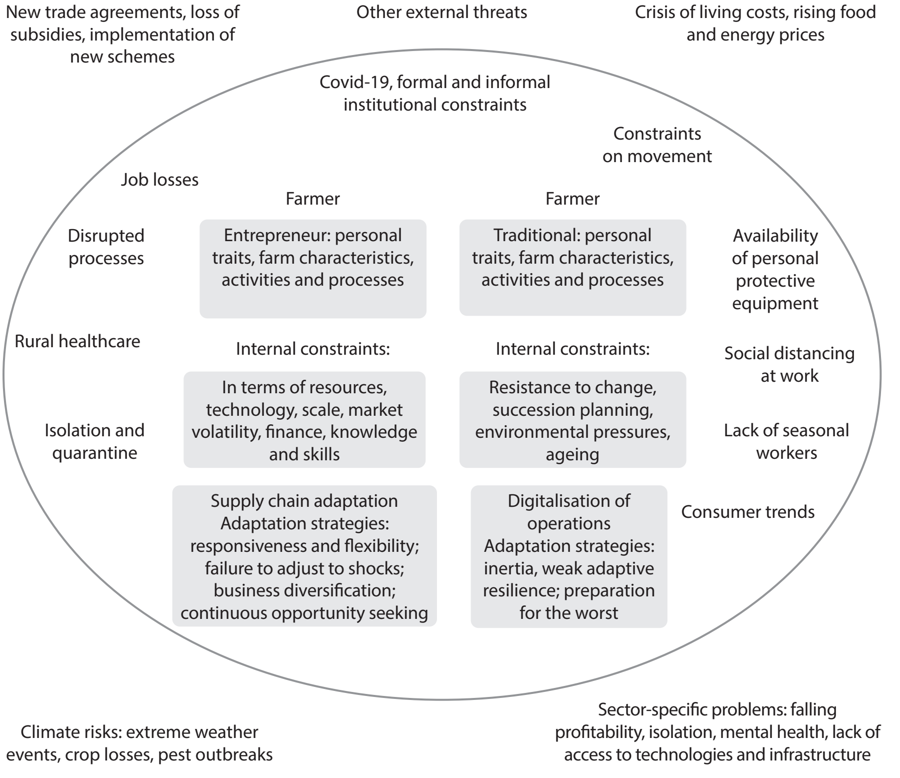
Anti-crisis strategies at farm level must be appropriately tailored to whether the holding is managed by a farmer-entrepreneur or by a traditional farmer[56]. The former group tends to be younger, better educated, and more familiar with general business operations. They are more likely to lease assets and demonstrate a greater willingness to adopt new technologies and innovations, as well as to take risks. They usually also maintain broader business and social networks. Their primary anti-crisis strategy is diversification. Traditional farmers, on the other hand, exhibit characteristics that are fundamentally different from those of farmer-entrepreneurs.

Although the literature stresses that the most effective strategy for prevention and dealing with crises at farm level is broad-based diversification, farmers should also be familiar with other strategies: increasing capacity, improving efficiency through new technologies and innovations, horizontal and vertical integration, "doing nothing", and exiting the agricultural sector altogether[57]. The core issue lies in the ability to construct an appropriate combination (portfolio) of individual risk management instruments, ideally suited to the specific conditions and type of crisis situation.

P. Gittins and G. McElwee, by integrating the existing theoretical and empirical contributions in the fields of CRE and CIC, and by analysing the behaviours of farmer-entrepreneurs and traditional producers, developed a conceptual model – the Farm Crisis Adaptation Framework (FCAF). It accounts for differences in their responses to crises, the rules guiding the selection of preventive strategies, and the ways of coping with adverse impacts. This model is presented in Figure 3[58]. Undoubtedly, it is a very interesting concept, but it is also worth exploring its further development – including the use of crises as opportunities[59].

56. P. Gittins, G. McElwee, *Farm adaptative business strategies in crisis management: Covid-19*, "Journal of Rural Studies" 2024, Vol. 111.
57. R. Smith, G. McElwee, P. Somerville, *Illegal diversification strategies in the farming community from a UK perspective*, "Journal of Rural Studies" 2017, Vol. 53.
58. P. Gittins, G. McElwee, op. cit., 2024.
59. W. Gleiβner, *Grundlagen das Risikomanagements: Hanbuch für ein Managemant unter Unsicherheit*, 4. Aufl, München, Vahlen, 2022; J. Kulawik, op. cit., 2022.

**Figure 3. General framework of agricultural holdings' adaptation to crisis situations (based on the example of Covid-19)**




*Source: Based on: P. Gittins, G. McElwee, Farm adaptative business strategies in crisis managemant: Covid-19, "Journal of Rural Studies" 2024, Vol. 111.*

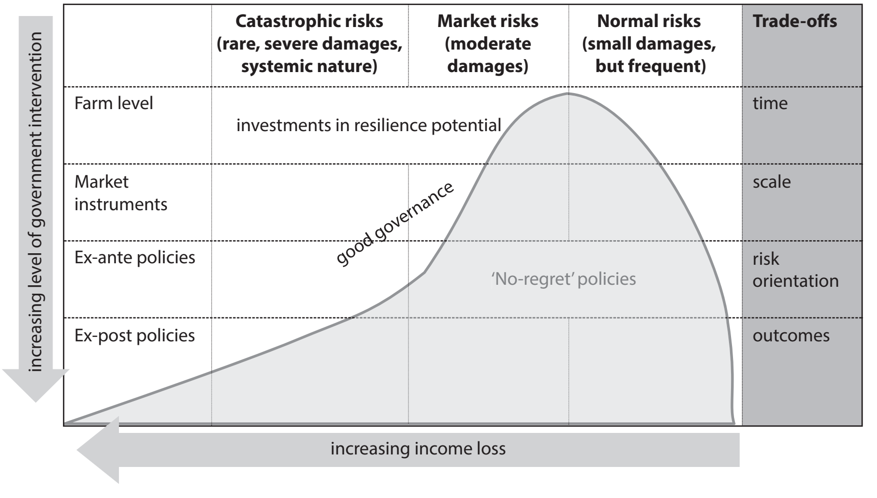
We generally owe the concept of holistic risk management in agriculture to researchers at the OECD, although the idea can also be found in the work of economists from the World Bank (O. Mahul and C.J. Stutley) and the Platform for Agricultural Risk Management (PARM). However, the OECD's framework is the most mature and – what is more – continues to be refined. The latest version developed by this organisation is presented in Figure 4.

This represents a further stage in the development of holistic risk management in agriculture designed by the OECD, and it marks a significant step forward, as evidenced by the title of the relevant report: "Strengthening agricultural resilience in the face of multiple risks"[60]. The emphasis on "resilience" – which should not be

60. K. Baldwin, E. Gray, *Strengthening agricultural resilience in the face of multiple risks*, OECD, Paris 2018.

reduced merely to "resistance" – is a result of the growing long-term and constant uncertainty facing agriculture, driven above all by climate change and market instability, particularly in relation to financial products and instruments. All actions that enhance resilience – i.e. the capacity to absorb shocks, adapt to them, and transform farming operations so they are better prepared ex-ante for future threats – also improve the quality of risk management. Naturally, there is also a positive feedback loop running in the opposite direction: from better risk management to stronger resilience. This system is illustrated in Figure 4. The "no-regret" policies shown in the diagram should be understood as horizontal actions aimed at improving the position of all entities and individuals in a given region, as well as those policies that should be discontinued if they do not deliver the expected outcomes.

**Figure 4. Holistic risk management in agriculture in the context of strengthening resilience**




*Source: Adapted from: K. Baldwin, E. Gray, Strengthening agricultural resilience in the face of multiple risks, Paris, OECD, 2018.*

Managing multiple catastrophic risks, especially those of a systemic nature, should take place at the level of individual countries as well as in an international dimension. In practice, this is very difficult. This results from three main causes:

1. Cognitive biases of people and their biological and psychological limitations in identifying, understanding and responding to phenomena that will occur only in

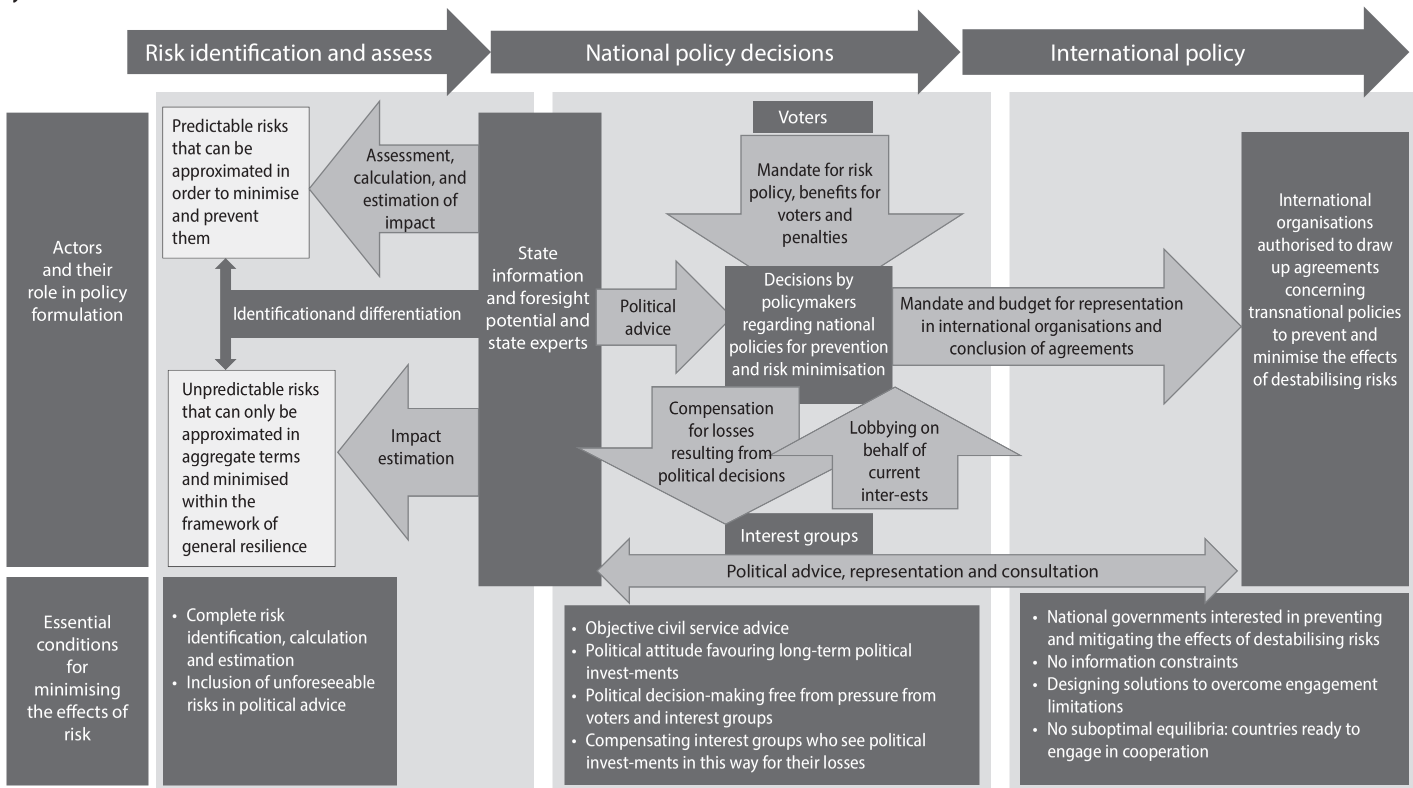
the distant future – rarely, but with significant damage potential[61]. These cognitive biases, also known as distortions, involve exaggeration and the reinforcement of certain patterns of thinking, which distort the perception of problems and may lead to irrational decisions. The extreme manifestations of such biases include depression and anxiety disorders.

2. Structural preferences in governance systems, particularly under liberal democracies, for policies and investments with short-term returns, due to the logic of political and electoral cycles[62].
3. Insufficient international cooperation[63].

As already mentioned earlier in this article, H.B. van Voss and J. Helsloot proposed a general framework for designing public policies for managing catastrophic risks with long-term, destabilising effects on economies and societies[64]. It is based on three pillars of rational policymaking: (1) the classification of risks in terms of their probability of occurrence and potential for damage; (2) the creation of a set of instruments with a clearly positive balance of benefits over costs incurred; (3) the implementation of resilient and coherent regulations, agreements and international arrangements. Of course, an appropriate public investment policy will also be needed – one capable of effectively addressing the challenge of short-termism and the bidding of populists of various kinds. At the same time, however, such a policy must guarantee citizens a sense of security, convince them of the long-term profitability of current expenditures and sacrifices, and strengthen the capacity of the state itself. These interdependencies are reflected in Figure 5. As can be seen, the layout is highly complex. Yet it is difficult to imagine it being any simpler, if one wishes to design an integrated policy for minimising threats linked to catastrophic and systemic risks. In fact, this framework would be even more complex if one sought to design such a policy within the convention of complex systems dynamics, which is, in truth, how it ought to be done[65].

61. K. Belton, K.M. Dhami, *Cognitive biases and debiasing relevant to intelligence analysis* [in:] *Handbook on Bounded Rationality*, ed. R. Viale, New York, Abindoo, Oxon, Routlege, 2022.
62. A. Jacobs, *Policy Making for the long term in advanced democracies*, "Annual Review of Political Science" 2016, Vol. 19, No. 1.
63. I.W.R. Martin, S.R. Pindyck, *Averting Catastrophes: The Strange Economics of Scylla and Charybdis*, "American "Economic Review" 2015, Vol. 105, No. 10.
64. H.B. Van Voss, J. Helsloot, op. cit.
65. J. Kulawik (red. nauk.), *Ryzyko katastroficzne i rezyliencja w gospodarce żywnościowej*, not published, Warsaw, IERiGŻ PIB, 2024.

**Figure 5. Constructing a national policy focused on preventing and minimizing the destabilizing long-term effects of the materialization of catastrophic and systemic risks**




*Source: Based on: H.B. von Voss, J. Helslost, How states deal with long-term destabilizing risks, "Journal of Risk Research" 2023, Vol. 26, No. 10.*

## Summary

Catastrophic risks, always and everywhere, constitute a serious challenge for public policy – particularly when they materialise as systemic risk. In general, they are difficult to model in insurance and reinsurance, and the results obtained are burdened with considerable uncertainty and imperfection, as they concern the evolution of threats extending even beyond the next two centuries. In future, the situation will certainly become even more complicated if current forecasts prove correct regarding the predominance of the negative consequences of ongoing climate change over its potential benefits – should the world fail to implement appropriate countermeasures. Of course, climate change further increases the complexity of modelling catastrophic risks in agriculture, which is already a highly demanding endeavour due to the biological nature of agricultural production and the high variability, both in time and space, of exposure to natural and, to some extent, anthropogenic hazards. It is therefore unsurprising that few catastrophe models have been implemented in the agricultural sector. Added to this are the challenges of constructing insurance schemes that provide protection against catastrophic risks, unless they are heavily subsidised, reinsured or subjected to alternative risk transfer (ART). There is greater potential in index-based insurance than in traditional schemes, but even so, it is extremely difficult to avoid situations where the state (via the budget) becomes the reinsurer of last resort, providing disaster relief to affected farmers. This should be accepted as a natural fact – disaster relief is a component of crisis management in agriculture and, if necessary, of crisis management at the national level or even on a broader scale. The Covid-19 pandemic and the likelihood of similar extreme events occurring in future directly indicate the need for the development of global solutions to global threats.

Under the Common Agricultural Policy (CAP), there are two tools specifically oriented towards managing catastrophic risks: the Income Stabilisation Tool (IST) and crisis interventions in selected sectors of the agri-food economy. However, IST remains a potential rather than an actual instrument, as it has only been implemented in northern Italy and solely with respect to milk and apple production. It is thus not surprising that most research on IST remains at the exploratory stage. The Italian implementation suggests that participation in mutual funds is strongly determined by certain personality traits of farmers themselves, a supportive legal, regulatory and economic environment, and positive experiences in participating in cooperatives and disaster relief funds, as well as in benefiting from crisis interventions. The latter, however, are often perceived as too limited and burdensome due to complex administrative procedures, which result in long waiting periods for real support. For the EU,

the integration of available instruments into a comprehensive risk management system remains a challenge – one that focuses more strongly on strengthening resilience, based on the philosophy of good governance, risk management, and horizontal "non-regret" policies. At the same time, the EU possesses less potential for implementing commercial catastrophic risk management instruments than Anglo-Saxon countries with well-developed, innovative and integrated financial markets.

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