Approach for Risk Assessment in Agriculture. Example from African swine fever in Bulgaria

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Abstract

There are different approaches for assessment of the economic consequences from infectious disease and other epizootic cases affecting agriculture. Agriculture is one of the economic sectors with high vulnerability to natural and epizootic risks. This is due to the biological nature of the production processes and the conditions under which it takes place. The goal of this study is to demonstrate a feasible approach to assess the risk outcomes represented by economic losses and costs incurred for fighting the epidemic based on the most recent African Swine Fever (ASF) outbreak in Bulgaria 2019–2020. ASF is a severe viral disease affecting domestic and wild pigs. In Bulgaria for 2019, as a result of the infection, the number of inventory pig number at the end of the year was 25% lower compared to the previous year, while the whole herd of available and slaughtered pigs for the same year decreased by more than 6%. This leads to losses and economic damage that can be used to assess the risk factor. Regarding the goal, the risk assessment in this case, which is deemed as a feasible way for risk assessment in agriculture thoroughly will be performed in terms of the probability of occurrence of the risk factor and the intensity of the damage it causes. The quantitative methods for estimating costs are used to assess the risk in pig industry. They include autoregressive model, where livestock and production are projected itself by a lag function. The Error Correction Model is also applied to minimize the adjustments and stochastic error. The applied method is an appropriate tool for evaluating the consequences of risk factors and other hazards in agriculture.

Key words: risk assessment; agriculture; swine fever; pigs

Подход за оценка на риска в земеделието. Пример с Африканската чума по свинете в България

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Резюме

Съществуват различни подходи за оценка на икономическите последици от инфекциозни заболявания и други епизоотични случаи, засягащи селското стопанство. Земеделието е един от икономическите сектори с висока уязвимост към природни и епизоотични рискове. Това се дължи на биологичното естество на производствените процеси и условията, при които те протичат.

Целта на това проучване е да предложи и апробира подход за оценка на риска от такива бедствия, представени чрез икономическите загуби и разходи, направени за борба с епидемията от последното избухване на Африканска чума по свинете (АЧС) в България – 2019–2020 г. АЧС е тежко вирусно заболяване, засягащо домашни и диви свине. В България за 2019 г., в резултат на заразата, броят на наличните свине в края на годината е с 25% надолу, в сравнение с предходната година, докато цялото поголовие с наличните и заклани свине се понижава с повече от 6%. Това води до загуби и икономически вреди, които могат да се използват за оценка на рисковия фактор. По отношение на целта, оценката на риска се счита за показателен начин за цялостна оценка на риска в земеделието и ще бъде извършена през призмата на вероятността от поява на рисковия фактор и интензивността на причинените от него щети. Количествените методи за оценка на разходите ще бъдат използвани за оценка на риска в свиневъдството. Те включват авторегресивен проектен модел, където поголовието и производството зависят от същите в предходните периоди. Моделът за коригиране на грешки също се прилага за минимизиране на корекциите и стохастичната грешка. Приложеният метод е подходящ инструмент за измерване на последствията от настъпили рискови фактори и от други рискови събития в земеделието.

Ключови думи: оценка на риска; земеделие; африканска чума; свине

Introduction

African swine fever was first confirmed by the Bulgarian authorities on July 3, 2019 in domestic pigs. ASF has been rampant to the north and east of us since much earlier, and the disease is transmitted in various ways, both through the migration of feral pigs and from contaminated materials transported by transport or humans. There is currently no vaccine or treatment for ASF. According to the FAO, mortality from the disease reaches 100% in infected animals (FAO). The socio-economic consequences of the virus are great, not only for farms, but also for markets, where with the outbreak of ASF epizootics there are deficits and rising prices. In China, where the first cases were reported in August 2018, 165 outbreaks were found in 32 provinces, with about 1,193,000 animals killed. According to Rabobank, the current epizootic situation will lead to a reduction in meat production to 25–30% (Food Navigator, 2020). The disease itself is highly contagious. The infection is transmitted through direct contact with sick domestic and wild pigs, as well as through faeces and body fluids, and indirectly through the handling of equipment or clothing of people who have been in contact with infected animals. The main way to fight the disease is through mass extermination of pigs in the affected areas, which is recommended by the European Food Safety Agency.

According to the World Organization for Animal Health (OIE), for the last 5 years from the beginning of 2016 to the middle of 2020, a total of 14,327 outbreaks of ASF have been detected in the world, mainly in Asia and Europe. The total number of affected animals for this period is 10.2 million domestic pigs. In addition, 17,938 outbreaks of ASF in feral pigs were reported. The total number of identified cases for these years reached 833 thousand, and 79% of these cases were reported in Europe. In total, for 4.5 years, the number of domestic pigs killed globally is 8.2 million (OIE). Although the majority of reported cases are in Europe, most animal losses are in Asia. Losses recorded in Asia account for 82% of all domestic or slaughtered domestic pigs, with China, along with Southeast Asia, at the epicentre of the continent's disease.

When ASF occurs in a country, trade bans on exports from the respective place follow. Strict trade policies in the event of the disease are one of the biggest side risks, affecting not only farms and places threatened by the virus, but also entire regions and sometimes countries that cannot sell animals, both abroad and face facing restrictions for the internal markets as well. The latest case from September 2020 is for Germany, which is the largest producer of pork in Europe (Food Navigator, 2020). There were cases of dead wild boars on the border with Poland, which immediately provoked trade reactions among some of the main importers of pork from there. In Germany and in the EU, they insist on the application of the regional principle, where the introduction of bans will be only for the places where there are established cases because blocking the export of pork from all over Germany will hit pig farming across the Union. For now, the reassurance is that the traces of dead wild boars found in Germany near the Polish border will not be transferred to industrial farms because otherwise there will be a severe crisis in the European market, with long-lasting consequences. In recent months, pork prices in Germany and the EU as a whole have been falling and are at one of the lowest levels since 2015, or 1.30 Euro/kg carcass weight. For comparison, at the same time last year they were 1.85 euros/kg.

The situation in Bulgaria regarding the disease shows that for the period from the announcement of the first cases to the end of 2019, about 45 outbreaks of ASF in domestic pigs have been reported, with 776 cases. The number of affected animals - dead or killed reaches 138.3 thousand heads, according to reports provided by the Bulgarian authorities in the OIE (OIE, 2019). The predominant number of cases concerns holdings where more than 100 pigs are affected, with the penetration of the disease in one holding leading to the destruction of all animals there. Thus, one of the factors that determine the risk exposure to this disease is the concentration of animals and the density of animal objects in a given area.

As a result of the measures to control the epizootic situation with ASF, measures were taken for voluntary slaughter of animals in private farms, type "backyard" in the summer of 2019, as the BFSA pays compensation to each site for disinfection in the amount of BGN 300 (FAS-USDA, 2019). There are no official data on how many animals are covered because very often these animals are not registered, but according to expert estimates their number is over 45 thousand, located in almost all areas of the country. The funds paid by the BFSA to private farms in 2019 is about BGN 8.6 million, for about 32 thousand farmers.

By the middle of 2020, 14 new outbreaks of ASF have been reported in the country. The number of cases in domestic pigs is 280, and the affected animals are 64,525. The predominant number of these cases are from the beginning of the year, affecting very large farms. Experience from other countries shows that ASF entering an area can continue to smolder and manifest itself after reaching the peak of the identified cases within 2–3 years, subject to strict and consistent biosecurity measures. The goal of this study is to demonstrate a feasible approach to assess the risk outcomes represented by economic losses and costs incurred for fighting the epidemic based on the most recent African Swine Fever (ASF) outbreak in Bulgaria 2019–2020.

Methodology

Agriculture is one of the economic sectors with high vulnerability to natural epizootic risks. This is due to the biological nature of the production processes and the conditions under which it takes place. The risk assessment in agriculture is performed in terms of the probability of occurrence of the risk event and the intensity of the damage it causes. All of the theories and concepts for assessing the risk in agriculture identify the intensity of the hazard and the likelihood its occurrence as the main vectors for risk determination. According to Carrão et al. (2016), the assessment of risk covers the hazard, the exposure, and the societal vulnerability, which are then combined to arrive at an assessment of the risk for significant impacts. In connection with such concept, Joint Research Center (2018) defines the risk "to incur damages and economic losses depends on the combination of the severity and the probability of occurrence of a certain event, the exposed assets and or people, and their intrinsic vulnerability or capacity to cope with the hazard".

A quantitative method for estimating costs is supposed to assess the risk in agriculture. The indicator method is a vast way used to assess the consequences and damages from the risk cases in agriculture. The indicators represent the identified consequences of the hazards and are expressed in calculation matrix as dependent variables. The calculation matrix is envisaged as a feasible way to assess the extent and scale of the consequences of risk cases because on annual basis, the agriculture is liable to various hazards that impairs the industry. Once the entire outcome from the natural hazard is aimed to evaluation, the variables of losses from affected crops and livestock are taken into account presented by the following equation:

$$Y_{111} + Y_{112} + Y_{11n}\ldots\ldots Z_{111} + Z_{112} + \ldots\ldots Z_{11n} = YZ_{11} \quad (1)$$

Y and Z are independent variables that show the intensity of damage caused by a particular disaster. The variable Y quantitatively reflects the intensity of the specific losses caused by the disaster, while Z stands for the amount of costs to deal with the damage under the measures taken. In the current infectious disease assessment the Z is not included due to lack of relevant data and because it is considered as secondary and the costs and efforts for implementation are relatively slight compared to same ones incurred by infectious or natural hazard. Ivanova and Ivanova (2017) in their methodology concerning evaluation of ASF formulate economic losses as a sum between direct cost and direct incremental costs, which to significant extent complies with Y and Z in the depicted methodology.

The risk assessment for African Swine Fever (ASF) is done evaluating the losses of dead and culled pigs for 2019, where pig classes (piglets, gilts, boars, sows) are standardized to 1 fattened pig. The losses from ASF are evaluated at annual base represented as their share in total pig production (Y), index of those losses in the livestock industry (X) and losses within Gross Agricultural Output (θ). The values of independent variables are normalized, and the primary value can take a value or natural expression. This is achieved by taking into account the share of measured damage caused by hazard event on the production sectors regardless it concerns ASF, crop or other livestock disaster. In order to evaluate Y, which stands for the annual losses in particular sector, the numerous or value measures of the damages are taken and it is divided to the total volume or value of the affected industries without disaster. It is depicted by the equation:

$$Y \text{ и } Z = \frac{\text{Costs or losses on crops and animal sectors caused by disasters}}{\text{Total amount of the affected crop and animal production}} \quad (2)$$

In order to compare the consequences and damages of different disasters and cases, the coefficients of the variables Y and eventually Z will be weighed, taking into account the share of each of the affected sectors in the total industry production or Gross Agricultural Output. The indices Y and Z show the share of sector losses by hazard type, while X and θ reflect Y in the agricultural industry and in the total agricultural output. By weighing the result of measuring the intensity of the damage from the various risk cases, the normalized value of the intensity and scale of the specific disaster will be obtained:

$$X_{AI} = W_{AI} * YZ_{nn} \quad (3)$$

$$\theta_{GAO} = W_{GAO} * YZ_{nn} \quad (4)$$

X and θ are indices showing the damage and losses from the different types of risks in terms of agricultural industry and Gross Output. The values of X and θ are in range far below 1 and X always is higher than θ. These indices are weighted by W_{AI} and W_{GAO}, which are shares of certain sectors in the higher agricultural production structure – crop or animal industry and agricultural output. At the same time, the indices X, Y and θ represent the losses from natural and disease hazards, where is thought the risk vector includes 3 components – prevention of occurrence of risk cases (α), calculation of losses and damages from the hazard (X, Y and θ) and compensation and mitigating the occurred damages (ω). This concept of risk is a matter of risk management envisaged from one side to deal with those components of risk vector and from other side to trade off between prevention and risk solution. Hubbard (2009) posits the risk “as a sort of vector quantity, which are quantities described only in two or more dimensions”. The calculation of X, Y and θ will allow to compare with the other components of this risk vector, as α and ω respectively represent the sums of all costs of preventive and follow-up actions to deter and compensate for the consequences of risk cases divided by the gross agricultural output in the last period before its occurrence.

$$\alpha \text{ or } \omega = \frac{\alpha/\omega_{111} + \alpha/\omega_{112} + \ldots\ldots\alpha/\omega_{11n}}{\text{Gross Agricultural Output}} \quad (5)$$

Principally, the sum up of α, θ, ω at annual base represents the total risk assessment in the vector term, which means α and ω are scalars whereas θ is a risk vector assessment. This allows these 3 components of the risk α, X, Y, θ and ω to be compared and a risk management based on different options to be applied.

To complete evaluation of Y, it is necessary to compare the real data for particular agricultural sector (i.e. pig sector) and potential pig number in case the hazard event does not appear. Thus Y is a function of Y_n, where:

$$Y_n = Y_{nR} - Y_{nP} \quad (6)$$

$$Y_{nP} = \beta_0 + \beta_{1*} Y_{mR-1} + \varepsilon \quad (7)$$

In order to minimize the error (ε) in the design prediction, modeling of the error is applied using the Corrected Error Model (ECM), which is:

$$\varepsilon = \beta_2 * Y_{nP} + \varepsilon^I \quad (8)$$

The variables Y_{nP} and ε^I are the dependent variables for the individual pig categories.

From there the following relationship is obtained:

$$Y_{nP} = Y_{nPt} - Y_{nPtavg} \quad (9)$$

The corrected error model is one of the most common tools in applied econometric modeling, which attempts to reduce the stochastic error and to fix the adjusting factor. *Hendry* (1980) specifies the closest expression to the ECM, where:

$$\Delta Y = \alpha + \beta\, \Delta X - \gamma\, (Y_{t-1} - X_{t-1}) + \varepsilon_t \quad (10)$$

In the present study, the corrective expression is $Y_{nPt} - Y_{nPtavg}$, which represents the difference between a given year and the average for the period. Regarding pig breeding, this is the difference in the design number of the respective category of pigs for a certain year subtracted from the average for the period under consideration. By calculating the functional relationship between the dependent variable Y_n and the adjusting factor εgreater accuracy of the design prediction (Y_{nP}) is achieved, which increases the reliability of the approach for estimating ASF risk losses.

Results

Pig farming is the largest sub-sector in meat animal husbandry and ranks second after dairy in the overall industry structure. Like other subsectors, it is shrinking in gross agricultural output, and the added value it contributes has declined in the years of EU membership. A report by the Institute of Agricultural Economics (2020) states this is happening “despite the fact that, on condition, livestock farming adds value to grain and fodder production”. The reason is that these productions due to their low productivity and difficulties in selling products at good prices and increasing costs for feed and animal husbandry fail to form a good return and efficiency (Institute of Agricultural Economics, 2020).

After 2007, intensified consolidation began in the pig sector, where the source of efficiency and return is scale and integration along the chain. These processes have led to a reduction in the number of farms and the exit from the sector of unprofitable ones. Gradually, this production stabilized, as things seemed volatile at the beginning and in the middle of the period considered. Stabilization is associated with growth in productivity and fertility, which is a key indicator of the condition and condition of any production. However, based on the development of the market and the stable demand, the country remains a net importer of pork, as the growth in the consumption of such meat is satisfied with a predominant increase in imports. At the same time, in the last 2–3 years there has been a more noticeable rise in domestic production, which has faced one of the unpredictable and external risks associated with infectious diseases such as ASF.

Pig farming marked a gradual upward growth after 2014, after between 2007-2014 a decline of about 39% in the number of pigs and a decline of about 12% in the production of pork. The inventory of the number and category of pigs shows that in the years between 2010–2018 there is a 20% increase in growing pigs up to 50 kg, while

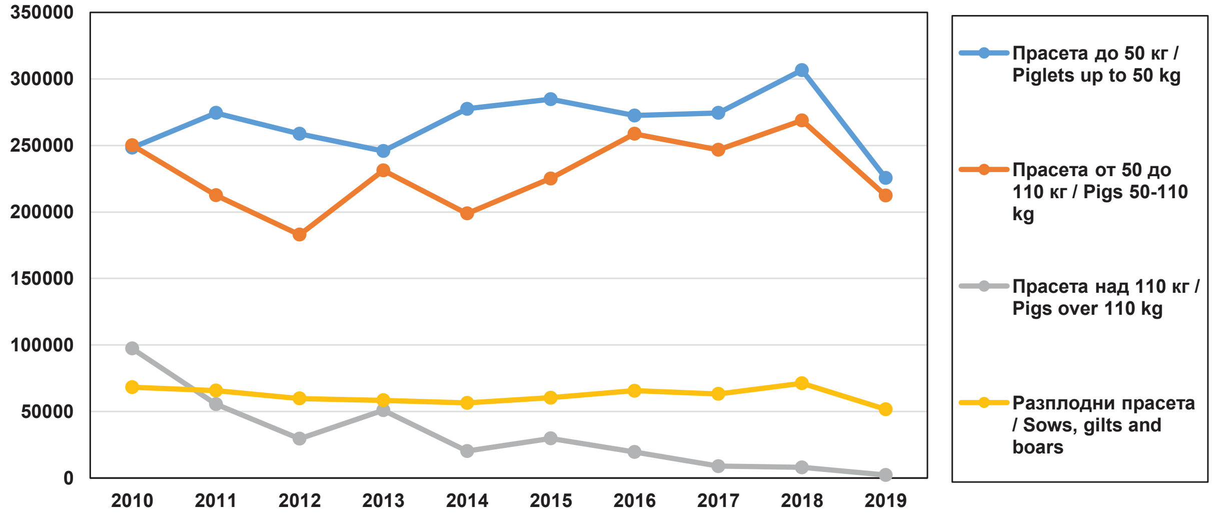


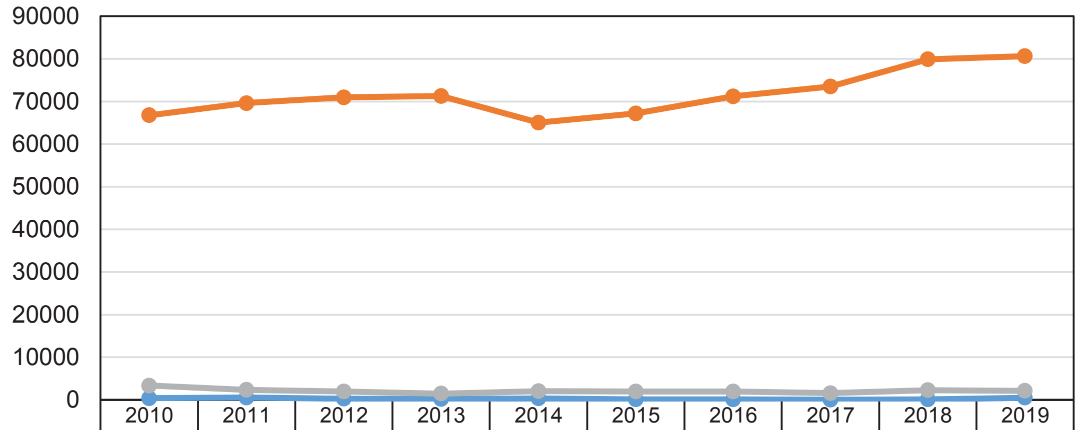
Fig. 1. Evolution of pig number by categories in Bulgaria, 2010–2019
Фиг. 1. Динамика на броя на свинете по категории, 2010–2019 г.
Source: Agrostatistics, MAFWE, and own calculations.
Източник: Агростатистика, МЗХГ, и собствени изчисления.

the other categories either remain at the levels from the beginning of the period or decrease dramatically, as is the case with already fattened animals. As of 2010–2011, their residual number at the end of the calendar year reached 97.3 thousand heads, while by 2018 the previous, fattened and slaughtered animals reached less than 10 thousand. However, the picture of livestock changed dramatically in 2019, when due to ASF, the final stocks of live pigs by about 25% on an annual basis. The largest decrease is in the categories of piglets and breeding pigs, where the reduction is about 28%, and the total number of the whole herd is reduced for the year by 163 thousand pigs.

In 2019, 1687 pig farms were counted in the country, and the available animals at the end of the year were 492 thousand. As a result of the restructuring, both relatively large (over 1,000 sows) and smaller (less than 1,000) pigs were established. 1,000 sows) pig complexes. In the farms with standard production over 500 thousand euros there are only 40 farms, which cover 87% of the economic production of the sector. Pork is the most consumed red meat in the country. Consumption is about 23 kg. per person and is among the lowest in the EU, which is about 45 kg per person, almost as much as in China, which ranks first in the consumption of pork in the world. It is also interesting that our neighboring Serbia consumes about 42 kg of pork per person. The other positive in the economic development of the sector is that 90% of breeding female animals (54 thousand heads in 2019) are in 45 farms, which shows the good conditions for economies of scale, but also reveals the risks in cases of such viral diseases that threaten both the economic and health security of the sector.

Although in terms of the final stocks of live pigs, their number has not changed significantly over the years and there is no clear increase, in the production of pork, the growth between 2010–2018 is 18%. In 2019, there is an increase in pork production, which is again explained by the measures to combat ASF, where many farmers voluntarily or necessarily take this action. The increase in meat yield in 2019 is 2% more on an annual basis.

Following the developed methodology, the studies of lesions and losses from swine fever in pigs, only for 2019 in the sector are estimated at 9.7% of gross production in pig production (Table 1). They are divided into direct losses, estimated at 3.2%, which come from destroyed and



	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Прасенца до 50 кг	387,2	556,5	266,3	212,6	356,4	148,5	123,1	63,6	148,6	506,8
Угоени свине	66729,5	69603,8	70951,3	71232,4	65008,6	67164,9	71159,7	73518,5	79900,8	80588,4
Други свине	3354,7	2345,3	1941,1	1459,8	2076,6	1946	1959,2	1578,5	2267,1	2094,5

Прасенца до 50 кг — Угоени свине — Други свине

Fig. 2. Production of pig meat by categories countrywide
Фиг. 2. Производство на свинско месо в страната по групи животни, тона – кл.т.

Source: Agrostatistics, MAFWE, and own calculations.
Източник: Агростатистика, МЗХГ, и собствени изчисления.

Table 1. Direct, foregone and total losses in pig sector due to ASF, 2019
Таблица 1. Директни и пропуснати загуби в свиневъдството поради АЧС, 2019 г.

	Действителен брой на поголовието / Real Pig number with ASF, 2019	Проектирано поголовие без АЧС / Projected Pig number without ASF 2019	Поголовие, загубено поради АЧС / Pig number lost due to ASF, 2019	Действително добито свинско месо / Actual Yield pork-meat at 2019 with ASF	Проектиран добив на свинско месо без АЧС / Projected porkmeat yield without ASF 2019	Общи загуби от АЧС / Total losses from ASF risk in 2019
Прасенца до 50 кг Piglets up to 50 kg	225571	299574	74003			
Прасета за угояване над 50 кг Pigs for fattening over 50 kg	214636	263939	49303			
Разплодни прасета Total sows and hogs	51606	64644	13038			
Общо поголовие на свинете Total Pig Inventory	491813	628157	136344			
Добито свинско месо Porkmeat, tons swt				83190	80442	
% на директните загуби от АЧС / % of direct losses from ASF in 2019						3,19
% на пропуснатите ползи от АЧС / % of foregone incomes from pig sector						6,49
Общо загуби / Total Losses, %						9,73

Source: Agrostatistics, MAFWE, and own calculations.
Източник: Агростатистика, МЗХГ и собствени изчисления.

dead animals. The number of lost animals projected is 136.3 thousand, which is about 2% less than declared as losses to OIE. At the same time, the projection for pork production in 2019, in a scenario without ASF, measures the volumes of 80.4 thousand tons, while in reality 83.2 thousand tons were obtained. The comparison of the real with the project data shows that as a result of ASF in the country were received about 2747 tons more pork, which indicates no loss of meat this year. This increase in production is largely explained by the preventive measures taken by many farms to slaughter their animals to prevent possible losses from ASF risk.

Along with the direct losses from ASF, pig farming is also exposed to indirect lost profits for future periods, which are also part of the variable Y. They result mainly from the losses of sows and breeding animals. According to actual data, breeding animals in 2019, together with breeding boars amounted to 51.6 thousand, while in 2018 they were 71.1 thousand pigs. In the absence of ASF, the number of this category of breeding animals is projected at 64.6 thousand, which reveals the lost future benefits, which are estimated at 6.5% by 2019. Receiving the lost benefits of additional reduction of breeding animals is calculated by multiplying the number of these breeding animals by the average fertility taken for 2018. Thus, the gross ASF losses for 2019 are estimated at 9.7%. According to the used classification 5-point scale for risk assessment in agriculture, this level can be defined as a low level of losses. These are losses according to equation (2) calculated between 3–10% of the total herd. The next 3 average grade is chosen in the range of 10,1–20%, the high grade is 20,1–30% and catastrophic, the proposed 5th grade is with losses over 30,1% of the annual livestock.

The wider impact of the ASF risk in 2019 helps to calculate X and θ, which is a consequence of losses observed in the share of pig breeding in the country's livestock and in total agricultural production. They are estimated at about 1.5%, which pig breeding has lost in livestock production, and direct and indirect losses in the sector amount to 0,4% of Gross Agricultural Production (Fig. 3). The full risk assessment in agriculture covers 3 levels of the risk event (prevention, losses, recovery and compensation) and related to the value

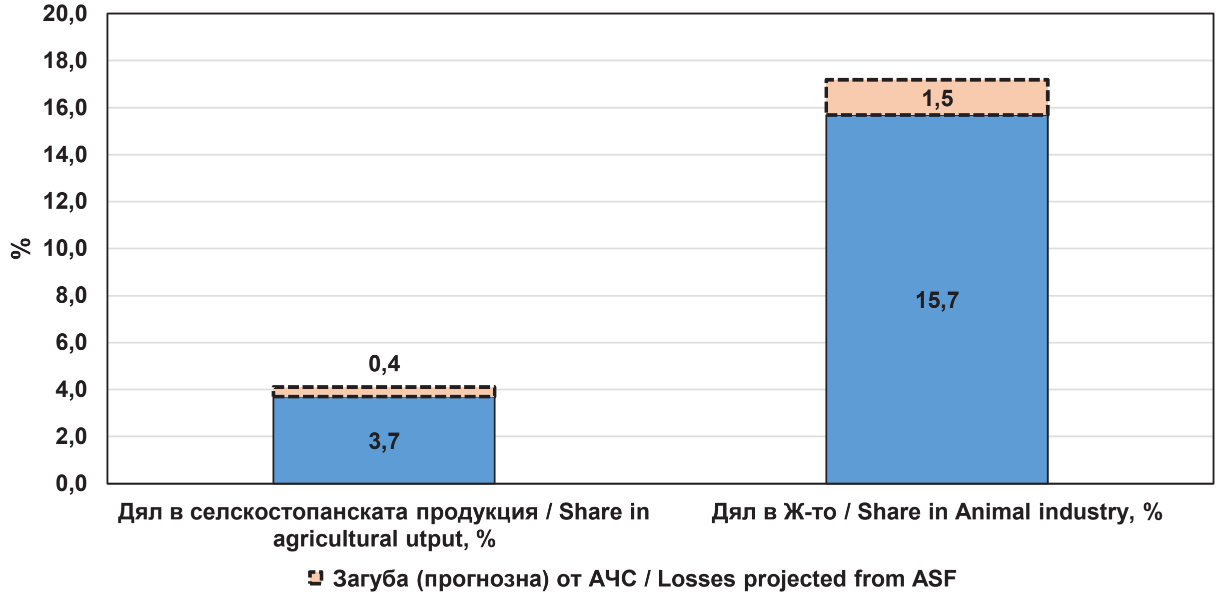


Fig. 3. Impact of ASF losses in pig sector in animal and agricultural output, 2019
Фиг. 3. Отражение на загубите в свиневъдството, в животновъдството и селскостопанската продукция, 2019 г.

Source: Own calculations based on NSI data.
Източник: Собствени изчисления по данни на НСИ.

added of agriculture for 2019. Including the calculation of ω to the assessment of losses must be added and compensation for killed animals and paid disinfection and voluntary slaughter of animals on small, self-sufficient farms. Alluding to USDA report for Bulgaria, the ASF related losses are judged at upward of 25 MEURO. In that relation, it can be estimated the losses defined as θ and ω in 2019 reach up to 1% of Gross Agricultural Output (USDA, 2019).

Conclusions

The risk factor for infectious and pathogenic diseases in animals depends on the contagiousness, the concentration of the animals, the availability of a vaccine or treatment, the mortality rate, the precautions. With industrialization and concentration in animal husbandry, the risks of potential losses will increase, which requires active risk management actions. African swine fever, as a vector-borne disease, threatens the economic sustainability of pig farming in Bulgaria, as well as the physical existence not only of domestic pigs, but also of the wild boar population, which are also subject to action to stop the spread of the infection. The study adopts a methodology for estimating the economic losses suffered in pig farming in 2019, which are defined as direct (dead, slaughtered and slaughtered pigs) and indirect (lost benefits from delayed reproduction).

The current, annual assessment of the losses from the occurred ASF epizootic establishes a level of 9.7%, only for the disease in the respective year, which gives grounds to qualify these damages as a low degree of the occurred risk. By assessing ASF losses, the consequences of such a disease can also be assessed when considering the individual hazards of infectious diseases. It can be argued that measures to deal with the effects of ASF, as well as to compensate affected farms, represent a significant part of the total losses. Some of these subsequent costs of dealing with the infection, especially for biosecurity, will play a preventive role in the future and reduce the risk of the disease entering. Economic optimization for ASF control and prevention must be in line with the size of the holdings, and the larger they are, the more measures and precautions must be taken. All actions to control and prevent ASF must be taken after a careful and reliable assessment of the risk of disease, which is an economically justified behavior that minimizes overall losses.

References

Carrão, H., Naumann, G., & Barbosa, P. (2016). Mapping global patterns of drought risk: An empirical framework based on sub-national estimates of hazard, exposure and vulnerability. *Global Environmental Change*, *39*, 108-124.

D. Hubbard. (2009). The Failure of Risk Management. Why it's broken and how to fix it". Published by John Wiley and Sons, Inc, Hoboken, New Jersey. https://webcache.googleusercontent.com/search?q=cache:7no2V3fljkUJ:https://canvas.uw.edu/courses/1066599/files/37549842/download%3Fverifier%3Dar2VjVOxCU8sEQr23I5LEBpr89B6fnwmoJgBinqj%26wrap%3D1+&cd=13&hl=bg&ct=clnk&gl=bg

Hendry, D. F. (2005). Predictive failure and econometric modelling in macroeconomics: The transactions demand for money. In *General-to-specific modelling* (pp. 535-560). Edward Elgar.

Ivanova, P., & Ivanova, E. (2019). Economic model for calculation of direct and indirect economical losses from African swine fever occurrence. *Bulgarian Journal of Veterinary Medicine*, *22*(2). https://www.researchgate.net/publication/332845765_Economic_model_for_calculation_of_direct_and_indirect_economical_losses_from_African_swine_fever_occurrence.

Институт по аграрна икономика. (2020). Анализ на състоянието на селското стопанство и хранително-вкусовата промишленост – SWOT анализ. https://www.mzh.government.bg/media/filer_public/2020/01/21/analiz_na_sstoianieto_na_selskoto_stopanstvo_i_khranitelno-vkusovata_promishlenost_izgotven_ot_institut_po_agrarna_ikonomika.pdf

Министерство на земеделието, храните и горите. Статистика и анализи. https://www.mzh.government.bg/bg/statistika-i-analizi/

Национален статистически институт. Икономически сметки за селското стопанство. https://www.nsi.bg/node/809

FAS-USDA. (2019). African swine fever. Update. GAIN Report – Bulgaria. https://www.fas.usda.gov/data/bulgaria-african-swine-fever-update.

Food and Agriculture Organization (FAO). 2020. Animal Production and Health. http://www.fao.org/ag/againfo/programmes/en/empres/ASF/index.html

Food Navigator. (2020). African Swine Fever hits Germany. What does it mean for the European Pork sector. https://www.foodnavigator.com/Article/2020/09/10/African-Swine-Fever-hits-Germany-What-does-it-mean-for-the-European-pork-sector?utm_source=copyright&utm_medium=OnSite&utm_campaign=copyright

Joint Research Center – JRC. (2018). Drought Risk Assessment and Management. A conceptual Framework. https://www.scribd.com/document/407795611/JRC-2018-Drought-risk-assessment-and-management-pdf. Pp. 68

World Organization for Animal Health – OIE. (2019). African Swine Fever – Bulgaria”. https://www.oie.int/wahis_2/public/wahid.php/Review report/Review?reportid=32218

World Organization for Animal Health – OIE. https://www.oie.int/en/animal-health-in-the-world/animal-diseases/african-swine-fever/