CLIMATE INVESTMENTS IN BULGARIA – POTENTIAL AND EMPIRICAL EVIDENCE

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Abstract: The study aims to establish the relationships between production and climate indicators in order to design a financial weather instrument in order to reduce the volatility of the financial performance of farmers in the region of Dobruja. For this purpose, a simulated weather derivative was designed and approbated making the relevant assumptions and constraints to mitigate the negative effects of changes in the levels of precipitation, the drought frequency, and the increasing climatic amplitudes on cereal crops. Its effectiveness is assessed taking into account the varying temperature and production and business performance of the agricultural producers. Last but not least, the study presents a critical review of the conditions required for the operation of this type of financial market in our country.

Key words: climate finance, climate investments, derivatives.

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Introduction

Climate investment is associated with climate risk and the related financial uncertainty. Generally, it is the risk of adverse effects caused by climate changes as a function of their volume and frequency. This type of uncertainty in the financial management of organizations requires adequate financing and management by means of appropriate financial instruments. Since the interest to this issue is increasing in sectors that are dependent on climate conditions, and in particular in the sector of agriculture, the possibility to design, implement and measure the efficiency of a weather derivative for a grain-producing agricultural cooperative in Bulgaria is approbated empirically.

The subject of this research are climate investments and in particular – weather derivatives.

Its object is the potential for development of this type of investment in Bulgaria analyzed by means of an empirical study, viz. a simulation of a weather derivative in terms of its design, implementation and effectiveness.

The aim of the study is to corroborate the implementation and present the possibilities to use weather derivatives with grain producers as well as study their feasibility taking into account historical climate and production trends.

Working hypothesis: climate investment is a new area that is still considered an avant-garde investment sector but offers opportunities for climate-dependent industries, such as agriculture, to minimize the volatility of their financial performance by mitigating losses incurred due to adverse weather conditions.

1. Weather derivatives as risk management instruments in agriculture

Climate risk has diverse effects and affects certain entities (such as agricultural producers) more than others. Moreover, it has different effects that depend on the type of the entity and weather anomaly. This is why climate risk can be categorized as correlated and uncorrelated in terms of its financial leveraging. Correlated risk refers to the simultaneous occurrence of many losses from a single event. Uncorrelated risks, in turn, are associated with low combined volatility as a result of events that affect a small number or individual entities. Therefore, the stock market is a suitable medium for mitigating correlated risks (i.e. risks that have an overall negative effect on the majority of investors) through derivative contracts. Uncorrelated risks are traded on insurance markets.

For the purposes of this empirical study, it should be noted that according to the classical understanding, agricultural crops are not subject to insurance because the underlying risks are correlated and therefore insurers cannot distribute and measure the risk exposures of their various customers. This problem is solved with derivative contracts that can leverage agricultural producers' risks.

Next, we need to distinguish weather from ordinary derivatives - the former are not backed by instruments traded on the spot market. In other words, weather conditions per se do not have value and climate change cannot be 'priced'. Therefore, the difference between weather derivatives and the other types of derivatives is that they are intended to hedge the risk associated with crop yields which affecting the overall financial performance of the organization. On the other hand, this type of instrument has certain limitations in terms of the underlying risk or the degree of correlation between the incurred losses and the selected climate index. If such a discrepancy arises, it is due to the fact that the amount to be received from the contract is based on certain climate dynamics and is not a direct consequence of reduction of the producer's yields.

The special case subject to the present empirical study is an agricultural grain production cooperative whose profits largely depend on its crop yields which are most sensitive to climate changes.

2. Empirical study – methodology

This analysis covers the four principal crops grown by a grain production cooperative in Dobruja: wheat, barley, sunflower and corn within a ten-year period – from 2009 to 2019. The data for the present study were acquired from two sources - the data on yields and financial indicators for the harvests were provided by the manager of the "East" agricultural cooperative in the town of Shabla. The temperature index values (heating and cooling degree days) for the region were obtained from Eurostat.

The information provided by the agricultural cooperative included: cultivated area (decares), yield, average yield (kg/dca), average selling price (BGN/ton), income from sales (BGN) for the four crops (wheat, barley, sunflower and corn) harvested annually by the agricultural cooperative from 2009 to 2019.

3. Designing a weather derivative for Dobruja grain producers

The derivative contract is based on seven parameters: the indices which determine the result of the contract, the type of contract, the coverage period, the closest weather station, the exercise price, tick (the amount that the contract holder receives for each day above or below the exercise price) and, if agreed, the maximum premium. The historical value of the index in a given region is the basis for determining the price of the derivative.

Analysis stages:

3.1. Turning temperature readings into degree days

The first step is to calculate the degree days index expressed as Heating degree days and Cooling degree days. Since two of the crops considered in this study (wheat and barley) are sawn and germinate during the colder period of the year while the other two (sunflower and maize) are sawn and germinate during the warmer months of the year, we had to make a hybrid type of index. We used the growing degree days index as a Heating degree days index for the colder period and as a Cooling degree days index for the warmer period.

Table 1

Dynamics of the Heating Degree Days index for the period 2009–2019 in the Dobrich province

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
2388.64	2522.05	2852.17	2567.38	2371.48	2455.70	2382.18	2490.70	2566.84	2421.51	2073.92

Source: Eurostat

The base temperature is set to 15ºC.

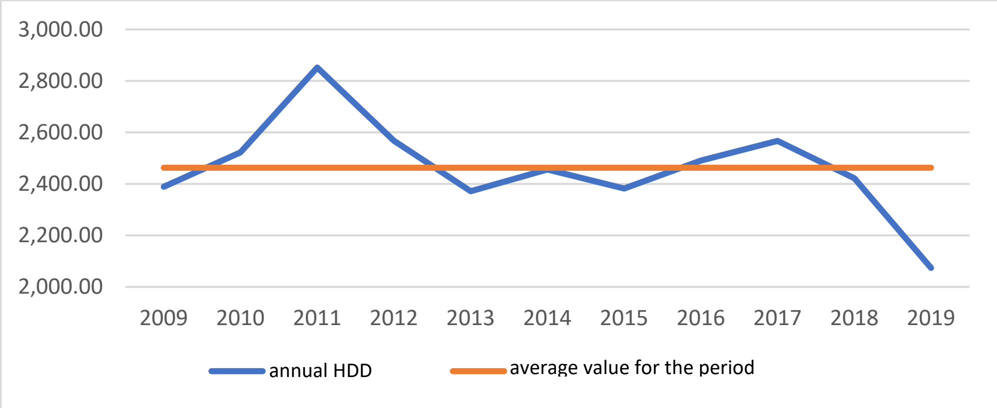
Table 2

Dynamics of the Cooling Degree Days index for the period 2009–2019 in the Dobrich province

2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
90.51	202.02	91.48	265.04	97.91	105.67	182.86	156.50	140.32	125.60	168.17

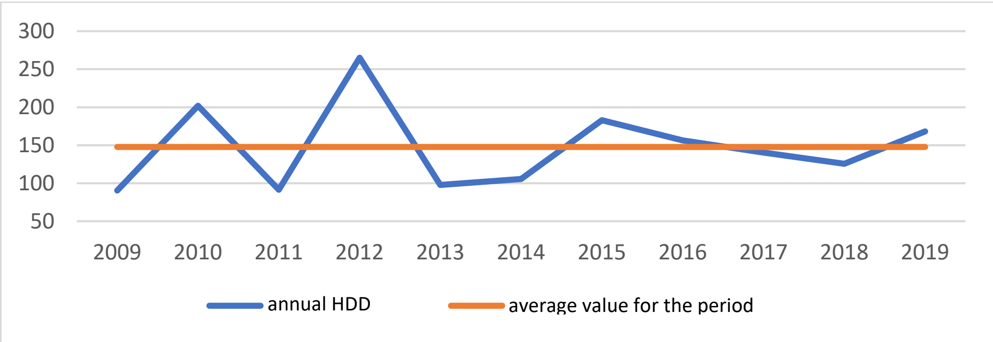
Source: Eurostat

The base temperature assumed to calculate this index for the warmer months is 24ºC. The aggregated indices are calculated through transformation of temperature data. The potential hedging positions are shown graphically as deviations of the annual aggregated indices from the average value of the index throughout the period:



Source: Author's calculations using data from Eurostat

Figure 1. ***Fluctuation of the Heating degree days (HDD) from the average value for the period 2009–2019.***



Source: Author's calculations using data from Eurostat

Figure 2. ***Fluctuation of the Cooling degree days (CDD) from the average value for the period 2009–2019.***

The graphical representation of these weather indices shows that there are broad opportunities for using hedging strategies based on their dynamics.

3.2. Choosing an instrument and exercise price

The most common types of weather derivatives are call and put options and swaps. The purpose of these instruments is to smooth income fluctuations, to hedge against losses, to redeem lost opportunity costs, to stimulate sales and to diversify investment portfolios.

The most important feature of weather derivative contracts is their exercise price. There are many approaches to its definition, described in the literature, but here we will focus on three that are mathematically and logically comparable for the purposes of climate hedging. Rustant, Lauren, Bay and Carraro (Roustant, O .; Laurent, J.-P .; Bay, X .; Carraro, L., 2003) propose the application of the historically average temperature index as a base exercise price (Option CU 1 in the table below). Garcia, A. F. and Sturzenegger (F., 2001) propose the calculation of a cumulative mean minus ½ from the standard deviation of the index for the analysis period (Option CU 2 in the table below). A third method is that of Platen and West (J., 2004), according to which the exercise price is equal to the average cumulative value of the index plus ½ from the standard deviation (Option CU 3 in the table below).

Let's choose a put option with a coverage period of 1 year and a tick of BGN 100 for each index unit. All three methods will be approbated to evaluate the effectiveness of the derivative.

Table 3

Statistical data for the heating degree days

min	max	mean	std.dev
2 073.92	2 852.17	2 462.96	178.6262

Table 4

Statistical data for the cooling degree days

min	max	mean	std.dev
90.51	265.04	147.83	51.93674

The actual result of the derivative contract is defined as:

$$p(x)_{agricultural\ producer} = \begin{cases} D(K_1 - x), & x \leq K_1 \\ 0, & K_1 < x < K_2 \\ D(x - K_2), & x \geq K_2 \end{cases},$$

where D is the step size, K_1 is the exercise price for the CDD, K_2 is the exercise price for the HDD, x is the degree days index value.

Table 4

Exercise price based on HDD index scenario

year	Heating Degree Days	Final result		
		Option CU 1	Option CU 2	Option CU 3
		2 462.96	**2 373.65**	**2 552.27**
2009	2388.64	7432.09	0.00	16363.40
2010	2522.05	0.00	0.00	3022.40
2011	2852.17	0.00	0.00	0.00
2012	2567.38	0.00	0.00	0.00
2013	2371.48	9148.09	216.78	18079.40
2014	2455.70	726.09	0.00	9657.40
2015	2382.18	8078.09	0.00	17009.40
2016	2490.70	0.00	0.00	6157.40
2017	2566.84	0.00	0.00	0.00
2018	2421.51	4145.09	0.00	13076.40
2019	2073.92	38904.09	29972.78	47835.40
Average value	2462.96	6221.23	2744.51	11927.38

Obviously, the highest results are achieved in Option 3, where the exercise price is relative to the mean plus the calculated standard deviation for the studied 10-year temperature monitoring period. The results follow the logic - with the increase of the exercise price the achieved result for the derivatives also increases.

In this case, the overall strategy of a put option is very successful and highly profitable. This approach would be very successful for hedging wheat and barley yields. The following table shows the analysis of the cold degree days index used to hedge sunflower and corn yields.

Table 5

Exercise price based on CDD index scenario

		Final result		
year	**Cooling Degree Days**	**Option CU 1**	**Option CU 2**	**Option CU 3**
		147.83	**121.86**	**173.79**
2009	90.51	5731.55	3134.71	8328.38
2010	202.02	0.00	0.00	0.00
2011	91.48	5634.55	3037.71	8231.38
2012	265.04	0.00	0.00	0.00
2013	97.91	4991.55	2394.71	7588.38
2014	105.67	4215.55	1618.71	6812.38
2015	182.86	0.00	0.00	0.00
2016	156.50	0.00	0.00	1729.38
2017	140.32	750.55	0.00	3347.38
2018	125.60	2222.55	0.00	4819.38
2019	168.17	0.00	0.00	562.38
Average value	147.83	2140.57	925.98	3765.37

Again, the third strategy turns out to have the highest added value, so we could conclude that, based on the index-calculated temperature for a region susceptible to correlated climate risks of a non-catastrophic nature, we can build a good hedging position with a profitable financial result choosing an exercise price, which is a calculation of the average index value for the period plus the standard deviation from all values for the studied period.

The calculated scenarios for exercise prices, and in particular option 3 will be used to analyse of the effectiveness of climate derivatives for the studied agricultural cooperative.

3.3. Measuring the effectiveness of weather derivatives for the financial and output performance of an agricultural cooperative

This section presents the climate derivative as an instrument intended to deal with non-catastrophic correlated risk based on the analysis and assessment of its effectiveness in mitigating the risk in the agricultural sector and in particular in grain production. The effectiveness of weather derivatives as risk mitigation instruments will be assessed on the basis of two groups of indices -

the first group includes the indices discussed in the previous section, i.e. the heating and cooling degree-days (TGD and SGD) depending on the particular crop. In addition to their historical values for the analysed period (2009-2019), the analysis includes their exponentially-smoothed projections for the period 2020-2025. Index values will be used to calculate the producer's hedging value framework.

The second main group of indices used as reference dependent variables for the climate change comprises the historical yields in the period 2009-2019 plus their projected values for 2020-2025. An important thing to note here is that we used the average yield (in kg/dca) for each crop in order to eliminate the effect of the varying sizes of land sown with each crop over the period. This two-dimensional approach with future and past values used to build the model for the effectiveness of the weather derivative will provide a more complete picture of the results and assess the instrument with both past and future development trends.

The developed model for calculating the historical and forecasting effectiveness of a weather derivative is intended as a tool for performing situation-specific calculations based on varying information regarding crop yields and input parameters over the analysed period, such as type of crop, location for calculating the cooling and heating degree-days indices, the size of sown areas and the tick size of the derivative. Taking into account the input data, the calculations start with finding the yield and the estimated yield per unit deviation of the index. This value was calculated for all four analysed crops and is based on the average yield (kg/dca) and the standard deviation of the heating degree-days for barley and wheat and the cooling degree-days for sunflower and corn. The obtained value, together with the historical and projected value of the income indicator per decare, form the first final variable of the model, namely – the historical and forecast value of the yields per unit deviation of the climate index (again calculated for summer and winter crops).

Table 6

Historical and forecast value of the yields per unit deviation of the climate index

Year	Yield/deviation Wheat	Yield/deviation Barley	Yield/deviation Sunflower	Yield/deviation Corn
2009	1.861	1.942	3.517	8.697
2010	1.808	1.569	4.657	8.031
2011	2.138	1.846	5.418	12.950
2012	1.842	1.851	5.703	8.269
2013	2.296	2.296	6.368	13.663
2014	3.315	2.516	6.178	20.102
2015	3.076	3.128	5.204	11.001
2016	3.061	3.501	5.869	15.207
2017	2.645	2.301	5.655	15.682
2018	2.344	2.971	5.798	19.318
2019	2.253	2.856	6.059	10.930
2020	2.851	3.326	6.206	16.351
2021	2.932	3.467	6.363	17.049
2022	3.014	3.608	6.520	17.748
2023	3.095	3.749	6.677	18.446
2024	3.176	3.890	6.834	19.145
2025	3.258	4.031	6.991	19.843

The second set of calculations in the weather derivative model is used to define its hedging function, the effectiveness of which will be measured in its entirety in terms of the final result of the application of the model.

Based on the historical and projected index values, the risk-free rate (based on the long-term yield of Bulgarian 10-year government securities, as well as forecast data for the period 2020-2025), the set time frame as primary data and the standard deviation of the index values for the period and the selected tick size, we calculated the amount of payment under the weather derivative contract and the amount of the premium. The expected result of the derivatives per unit change in the index is calculated using the following equation:

$$E_p = D\sigma[\frac{K-\mu}{\sigma}]^1,$$

[1] Equation adopted fromo Alaton, P., Djehiche, B., Stillberger, D. (2002). On modelling and pricing weather derivatives. Appl. Math. Financ. 9, 1–20.

where D is the tick size (assumed to be BGN 100) or the equivalent value per unit change of the index; σ is the standard deviation of the index value, μ is the average value of the index for the period. K is the strike value already calculated at the previous stage as the average aggregated value of the index plus ½ of the standard deviation.

Table 7

Expected result from the derivative per unit change of the index

Unit change HDD	Unit change CDD
19964.73	2319.80

The price of the derivative is calculated as[2]:

$$c = e^{-r(u-v)} E_p,$$

where **c** is the price paid by the buyer of the contract, r is the risk-free return rate (10-year Bulgarian Treasury Bills), v is the date of issue/purchase of the contract, and u is the date on which the contract was called/terminated. Ep is the expected payment based on forecast or historical mean temperature values (Sun, B., & van Kooten, G., 2015).

Table 8

Historical and forecast annual premium size

Year	Premium HDD	Premium CDD
2009	143856.30	30324.63
2010	143084.09	30161.85
2011	142571.42	30053.78
2012	141074.11	29738.15
2013	132121.30	27850.91
2014	131326.58	27683.39
2015	118572.86	24994.93
2016	100470.42	21178.97
2017	106914.50	22537.37
2018[3]	0.00	0.00
2019	61620.86	12989.56
2020	57980.86	12222.25
2021	57980.86	12222.25
2022	53525.86	11283.15
2023	57980.86	12222.25
2024	61620.86	12989.56
2025	53525.86	11283.15

[2] ibid.

[3] The value of „0“ for 2018 is due to the value of the risk-free return rate (=0) used to calculate the premium.

The three components calculated above to give us the total hedging amount of the derivative taking into account the variance of the three underlying indices are:

- Monetary value of historical yields and estimated yields per unit deviation of the temperature index;
- Historical and forecast return from the derivative per unit deviation of the temperature index;
- Premium calculated using the above formula.

Table 9

Hedging value of the derivative per unit deviation of the temperature index, annual

	Total hedging of the derivative per unit deviation of the temperature index (in BGN)			
Year	**Wheat**	**Barley**	**Sunflower**	**Corn**
2009	181 006.01	182 629.51	38 482.59	50 499.06
2010	179 183.29	174 408.26	49 761.85	63 961.85
2011	185 260.15	179 434.62	52 853.78	84 553.78
2012	177 841.81	178 032.81	53 738.15	64 538.15
2013	177 961.55	177 961.55	54 650.91	85 350.91
2014	197 508.44	181 559.86	53 683.39	112 283.39
2015	179 979.70	181 030.20	46 894.93	71 294.93
2016	161 590.75	170 376.80	45 878.97	85 178.97
2017	159 726.29	152 850.25	46 337.37	88 537.37
2018	46 795.26	59 305.82	24 400.00	81 300.00
2019	106 601.60	118 634.67	38 489.56	58 989.56
2020	114 896.42	124 376.13	38 341.15	81 035.37
2021	116 521.07	127 192.70	39 002.00	83 975.07
2022	113 690.72	125 554.28	38 723.74	85 975.67
2023	119 770.36	132 825.85	40 323.70	89 854.49
2024	125 035.01	139 282.43	41 751.86	93 561.50
2025	118 564.65	134 004.00	40 706.30	94 794.79
Total for the forecast period	708 478.23	783 235.39	238 848.74	529 196.89
Total for past years	1 753 454.85	1 756 224.36	505 171.48	846 487.95
Total for the forecast period	118 079.71	130 539.23	39 808.12	88 199.48
Total for past years	159 404.99	159 656.76	45 924.68	76 953.45

More interesting is the effect of the unit change of the temperature index as a percentage of the total yield of each crop.

Table 10

Effect of the unit change of the temperature index as a percentage of the total yield of each crop

	Unit change/total actual yield			
Year	**Wheat**	**Barley**	**Sunflower**	**Corn**
2009	21%	113%	10%	17%
2010	13%	118%	5%	15%
2011	12%	59%	6%	11%
2012	12%	124%	3%	11%
2013	12%	85%	7%	15%
2014	12%	73%	5%	16%
2015	12%	74%	5%	17%
2016	11%	126%	5%	17%
2017	13%	130%	5%	16%
2018	4%	41%	3%	14%
2019	10%	72%	5%	14%

Another interesting calculation refers to the number of contracts needed to achieve the full hedging of the derivative:

Table 11

Number of contracts needed to achieve the full hedging of the derivative

	Number of derivative contracts[4]			
Year	**Wheat**	**Barley**	**Sunflower**	**Corn**
2009	11.06	11.16	4.62	0.16
2010	59.29	57.71	-	-
2011	-	-	6.42	0.10
2012	-	-	-	-
2013	9.84	9.84	7.20	0.09
2014	20.45	18.80	7.88	0.06
2015	10.58	10.64	-	-
2016	26.24	27.67	26.53	0.02
2017	-	-	13.84	0.04
2018	3.58	4.54	5.06	0.06
2019	2.23	2.48	68.44	0.01
2020	3.43	3.71	16.84	0.03
2021	1.77	1.93	17.98	0.03
2022	2.93	3.23	18.78	0.02
2023	2.88	3.20	20.64	0.02
2024	2.83	3.15	22.62	0.02
2025	2.53	2.86	23.42	0.02
Average:	**11.40**	**11.49**	**18.59**	**0.04**

[4] With "-" is denoted the lack of exercised contracts due to the value of the exercise price for the corresponding indices.

Based on the number of contracts obtained, we will calculate the total hedge price based on the already calculated premiums depending on the two temperature indices (HDD and CDD) for winter and summer crops.

Table 12

Hedge price to achieve the full hedging of the derivative

	Hedge price (in BGN)			
Year	**Wheat**	**Barley**	**Sunflower**	**Corn**
2009	1 591 286.20	1 605 559.03	140 119.69	5 001.18
2010	8 482 750.97	8 256 695.52	-	-
2011	-	-	192 975.55	2 925.76
2012	-	-	-	-
2013	1 300 513.89	1 300 513.89	200 580.01	2 476.17
2014	2 685 826.98	2 468 949.44	218 152.46	1 679.59
2015	1 254 641.88	1 261 964.98	-	-
2016	2 636 678.99	2 780 041.08	561 859.06	430.00
2017	-	-	311 981.77	852.08
2018	-	-	-	-
2019	137 322.61	152 823.43	889 007.54	123.84
2020	198 897.88	215 308.26	205 762.71	343.50
2021	102 703.78	112 109.95	219 711.88	315.78
2022	156 626.77	172 970.69	211 915.26	270.58
2023	167 203.81	185 429.76	252 228.97	265.78
2024	174 268.14	194 125.55	293 769.57	256.31
2025	135 338.78	152 962.43	264 220.18	206.91

Having obtained this information, we can proceed to calculate the most important value – the net value of the hedging strategy (i.e. the hedging value or the price paid to hedge).

Table 13

Net value of the hedging strategy

	Net value of the operation (Hedge-Price)			
Year	**Wheat**	**Barley**	**Sunflower**	**Corn**
2009	410 936.53	432 742.12	37 695.16	3 327.20
2010	2 140 143.63	1 807 567.47	-	-
2011	-	-	146 398.99	5 305.62
2012	-	-	-	-
2013	451 220.82	451 220.82	193 011.42	5 112.21
2014	1 353 519.05	944 389.27	204 886.92	5 132.79
2015	649 757.36	664 730.34	-	-
2016	1 604 001.49	1 934 326.71	655 268.88	1 299.39
2017	-	-	329 460.22	2 495.30
2018	167 461.67	268 971.62	123 534.50	4 819.38
2019	100 239.98	141 397.68	1 745 224.50	438.55
2020	195 243.50	246 554.66	439 713.98	1 933.95
2021	103 694.58	133 825.83	481 403.01	1 853.84
2022	176 053.74	232 762.37	515 377.64	1 791.21
2023	178 187.10	239 363.30	579 925.82	1 688.18
2024	179 339.70	244 658.96	650 483.18	1 589.83
2025	164 448.95	229 984.78	689 009.04	1 531.40

Based on the results obtained, we could conclude that this hedging strategy could contribute to results that repeatedly pay the price and secure the position of grain producers. The projected values also prove that investing in a climate derivative based on the HDD and CDD indices or their theoretically defined equivalent Growth Degree-days index makes sense.

To summarize, the proposed model uses the input data to identify:

- The historical and forecast relationship between the degree-days index values and the income per decare;
- The historical and forecast relationship between the degree-days index values and the yield per decare;
- The potential hedging of the agricultural cooperative using the climate derivative under the assumptions and conditions of the model;
- Economic losses due to variation of the index values;
- A derivative contract with a set tick size and its capacity to hedge potential economic losses;
- The price of the weather derivative in terms of its premium;
- The payment from a weather derivative per unit change in the temperature index.

Given these parameters and relationships, the farmer/cooperative would be able to easily forecast the risk of loss based on different inputs as well as their preferences for period, exercise price, etc.

The ultimate goal of the model is to determine the hedging potential of a given producer depending on the yields per decare of selected crops and the distribution of the temperature index. Here, however, comes the question, given the efficiency of the derivative for the agricultural producers and the amounts they would possibly receive from the exercise of the index-based weather derivative, who would pay the price? This type of contracts may be traded on the stock exchange or at the over-the-counter market. If they are traded on the stock market, following the example of the Chicago Stock Exchange, they may be standardized contracts that can be traded publicly on the BSE or through electronic auctions (online), and their prices can be negotiated continually by the market participants which will guarantee total transparency of the trade with these instruments. If they are traded over-the-counter, where weather derivatives are based on individual agreements between the parties, then the prices and the terms of the contracts be negotiation by the parties in each separate case.

Conclusion

The effective implementation of weather derivatives in Bulgaria to provide hedging for agricultural producers requires an appropriate investment environment and government regulations to encourage the trade in producers' risks. This would also be a profitable strategy for the state, because the need for subsidies due to bad weather conditions and lost yields can be replaced by a market in which such risks are "bought" by private investors and farmers are compensated for their losses.

The developed model proves the feasibility of weather derivatives to compensate producers in absorbing losses as a result of correlated, non-catastrophic risks. Temperature index contracts have been proven to reduce the costs of climate change for farmers and society if there are incentives and a suitable financial environment for their use. It is important to increase producers' knowledge and awareness of these tools to reduce risks and potential losses. Once this is achieved, there will be a critical mass of producers for the establishment of an over-the-counter market for such contracts.

References

Желязкова, В. (2013). Климатичните промени и екологичният риск в дейността на финансовите институции. С. Издателство "Св. Григорий Богослов".
Недев, Т. (2008). Борси и борсови сделки. С.: УИ „Стопанство“.
Alaton, P., Djehiche, B., Stillberger, D. (2002). On modelling and pricing weather derivatives. Appl. Math. Financ. 9, 1–20.
Platen, E. and West, J. (2004): Fair Pricing of Weather Derivatives, working paper, http://www.qfrc.uts.edu.au/research/research_papers/rp106.pdf
Roustant, O., Laurent, J.-P., Bay, X., Carraro, L. (2003). Model Risk in the Pricing of Weather Derivatives, http://www.emse.fr/spip/IMG/pdf/Model_Risk_ Pricing_Weather_Derivatives-2.pdf
Spaulding Aslihan & Kanakasabai Murali & Hao Jianqiang & Skees Jerry. (2010). "Can Weather Derivative Contracts Help Mitigating Agricultural Risk? Microeconomic Policy Implications for Romania," EcoMod2003 330700139, EcoMod.
Stulec, I., Petljak, K., Bakovic, T. (2016). Effectiveness of weather derivatives as a hedge against the weather risk in agriculture. Agric. Econ. – Czech, 62: 356-362.
Sun, B., & van Kooten, G. (2015). Financial weather derivatives for corn production in Northern China: A comparison of pricing methods. Journal of Empirical Finance, 32, 201-209.
Thornes, John.E. (2006). An Introduction to whether and climate derivatives. Whether, vol.58, p. 193-196.
Vedenov, Dmitry V. & Barnett, Barry J. (2004). "Efficiency of Weather Derivatives as Primary Crop Insurance Instruments," Journal of Agricultural and Resource Economics, Western Agricultural Economics Association, vol. 29(3), pages 1-17.
Zeng, L. (2000) Weather derivatives and weather insurance: Concept, application, and analysis. Bull. Am. Meteorol. Soc., 81, p.2075-2082
Евростат: https://ec.europa.eu/eurostat/data/database

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