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Analysis of economic risk in potatoes cultivation

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Abstract: A number of variables influences potatoes growing, including natural conditions, used growing technologies and market conditions. The most important parameters for the production of potatoes crops are yield, farmer's price, subsidies and costs. All these parameters can change over time. This means that managers of farms must constantly assess the key parameters affecting the economic outturn and analyse the degree of risk of their achievement. This article analyses the economic risks of potatoes cultivation based on statistical data obtained over the last 10 years. The Monte Carlo stochastic simulation method was used to analyse the risk of gross profits. The results of the calculations confirmed the considerable variability and risk of growing potatoes in the climate conditions of the Czech Republic in general, and especially regarding the first early potatoes and potatoes for starch production.

Keywords: break-even point; gross profit; Monte Carlo method; risk analysis

Potatoes belong to the major market crops in the Czech Republic. As published by Zizka (2018) the arable potatoes production in the harvest years 2017–2018 amounted to 29 433 ha, of which 23 418 ha was produced in the agricultural sector and 6 015 ha in the production for self-consumption of households. In the agricultural sector, 692.0 thousand tons of potatoes were harvested whilst in the private household sector, 127.7 thousand tons were grown; this makes a total of 819.7 thousand tons potatoes produced in the Czech Republic. However, 151.5 thousand tons of potatoes were imported from other countries.

This summary shows that the Czech Republic is not self-sufficient in the production of potatoes. This is particularly due to lower economic attractiveness and a higher risk of not making a profit. There is a relatively high share of self-supply in the private household's potatoes cultivation; moreover, the competition with other crops (especially more profitable oil-bearing plants) on the market is causing a considerable reduction in potatoes production in the Czech agricultural sector.

Yields and farmer prices make the market output. These two components of market production are under the influence of the market environment on the one hand and under the influence of weather and the level of adherence to technological discipline in the enterprise on the other hand. Technological discipline means strict adherence to the set rules and correct sequence of all operations and their technological (cultivation) parameters.

Strict adherence to technological discipline also has an impact on input prices, which are reflected in costs (Foltyn et al. 2009; Spicka et al. 2009; Cizek 2014), both in items that the farmer cannot influence (purchase prices, taxes, rent, fees), and to items

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that can influence their decisions (numbers of operations, sets, bills).

Crop models are increasingly being used for different purposes, including evaluation of climate change impacts on crop yields and the opportunities for management to adapt to future conditions (Marin et al. 2017). According to Rayburn (2009), the possible benefits of using the stochastic methods are improved performance and better economic results of the respective agricultural company.

Gleissner and Berge (2004a) used the random number generation algorithm in order to model risk situations based on predetermined conditions and statistical distribution. Hyndman and Fan (1996); Koenker and Zhao (1996); Koenker and Hallock (2001); found out by examining the efficiency of crop growing that the number of risky situations, which can occur (meaning technical, technological, manufacturing, economic or market risks) is rather high. Therefore, they recommended solving the statistical division by using the quantisation method, which divides the set of values into several equal parts.

A number of intertwined factors have an influence on potatoes growing. No greater attention has been given to the analysis of economic risks of potatoes cultivation in the conditions of the Czech Republic so far. Therefore, this paper analyses the risk of not reaching the expected gross profit and examines the reversal point in practical terms.

MATERIAL AND METHODS

The monitoring of performance parameters of growing potatoes (particularly ware and seed potatoes, starch as well as early potatoes) took place from 2008 to 2017. The data obtained during the monitoring period were used for further analysis. Based on the results of the cost analysis, the following key parameters with the greatest influence on the gross profit were identified: yield, farmer prices and costs. Based on the above findings, an analysis of the risk of not achieving an average annual gross profit from potatoes production was carried out.

The modelling is based on the principle of generating random values (Gleissner and Berge 2004b) within boundary conditions for their triangular statistical distribution (Evans et al. 2000). The input parameters are always based on optimistic and pessimistic estimations of the parameter and on its most frequent occurrence, which is a so-called distribution peak.

The risk analysis was conducted with the aid of the stochastic Monte Carlo simulation method's algorithm; its principle was described by Kroese et al. (2011), concerning generating a pseudo-random variable for input parameters. The calculation principle is based on simulating a critical variable using 100 000 simulations (of risk situations) and constructing a two-sided frequency distribution interval at a materiality level of 0.05. The mathematical model created in Microsoft Excel using the Add-In is utilised to determine the mean value of a magnitude that results from a random sample. Consequently, data obtained through simulations can be statistically evaluated.

Parameters, which are likely to change, were selected. With regard to market production, the parameters concern changes in the potatoes yield and farm prices related to one hectare of potatoes. On the cost side, they concern changes in total costs related to one hectare of potatoes. As a reference parameter, the value of gross profit (GP; Relation 2) has been selected.

Yield values were generated based on the input "Average yield of potatoes" analysis and on the "Marginal conditions used for modelling"; values of the farm price, according to "Average farmer prices of potatoes" and "Marginal conditions used for modelling", and cost values, according to "Total costs of potatoes" and "Marginal conditions used for modelling". For the calculation of an approximate probability distribution, the so-called tree-point estimation technique was used.

Based on the values "Average yield of potatoes", "Average farmer prices of potatoes" and "Total costs of potatoes" parameter values of pessimistic estimate (*PE*); most likely estimate (*ML*) and optimistic estimate (*O*) were "Marginal conditions used for modelling" determined as follows:

For *PE*: mean value from the values of the relevant time series after the deletion of the two most advantageous values;

For *O*: mean value from the values of the relevant time series after the deletion of the two least advantageous values;

For *ML*: mean value from the values of the relevant time series after the deletion of at least one and the most advantageous values.

Market production (*MP*) is set as:

$$MP = Y \times P \quad \text{(EUR/ha)} \tag{1}$$

where: Y – yield (t/ha); P – price (EUR/t)

Market production increased by subsidies (*MPS*) is set as:

$$MPS = Y \times P + SY \quad \text{(EUR/ha)} \tag{2}$$

where:

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Table 1. Average yield of potatoes (t/ha)

Utility type	Year									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ware	25.50	25.60	23.20	28.80	27.40	21.60	26.90	21.70	29.70	30.80
Seed	21.30	23.10	22.80	23.80	23.40	19.40	21.50	18.10	23.80	22.80
Starch	32.30	31.20	30.30	47.80	33.40	33.00	38.40	21.80	37.80	36.10
Early	16.36	17.34	16.84	17.32	16.78	14.48	19.04	17.29	21.21	17.72

ware – ware potatoes; seed – seed potatoes; starch – potatoes for starch production; early – early potatoes

Source: CSO (2018), PRI HB (2018)

SY (subsidy) = SAPS (Single Area Payment Scheme) + coupled subsidies

Gross profit (*GP*) is set as:

$$GP = MPS - TC \quad \text{(EUR/ha)} \tag{3}$$

where: *TC* – total costs (EUR/ha)

Subsequently, this question was determined for the model: "Which risk can be expected when a certain value of gross profit is reached by changing the parameters?". Interpretation of the risk is also reflected in the results of the calculation. In general, the interpretation of risk does not follow a clear rule (Wolke 2008). The limit of the permissible risk of the project depends on the manager's attitudes as well as on the risks, which cannot be influenced – like, for example, the development of world market prices. The risk margins of one commodity often correspond to the risk level of other commodities, which are included in the portfolio of the managerial entity. Risk estimates (i.e. pessimistic, optimistic and unexpected) applied in the analysis of economic risks of potatoes production were based on a qualified analysis of the production and the specific market situation in the Czech Republic.

For the risk analysis, the gross profit was used; which is an important indicator for managerial decision-making. The gross profit criterion is based on the principle of neoclassical economic theory, which focuses on profit maximisation when taking decisions. Planting technologies are also affected by natural influences and market conditions, which the agricultural company cannot control itself.

Analysis of the parameters for calculation

Yield. According to the monitoring results from Czech Statistical Office (CSO 2018) and Potato Research Institute Havlíčkův Brod (PRI HB 2018), the average potatoes yields (Table 1) have been in the past 10 and 5 (10/5) years as follows: 26.12/26.14 t/ha for ware potatoes; 22.00/21.12 t/ha for seed potatoes; 31.09/33.42 t/ha for starch potatoes; 15.70/17.95 t/ha for early potatoes.

When comparing the average of the yields over the last 10 and 5 years, we can observe that there is a slightly increasing trend. Therefore, the marginal conditions of the average values assessed over the last 10 years have been determined for modelling. By analysing these data, the marginal conditions for the triangular statistical distribution, according to Table 2 were taken.

Table 2 displays marginal conditions used for modelling of gross profit.

Farmer prices. The farmer's price of potatoes is directly dependent on the growing year and the seed species with the relevant market orientation.

According to the CSO (2018) and PRI HB (2018) monitoring, the average value of the price for the last

Table 2. Marginal conditions used for modelling

	Utility type	*PE*	*ML*	*O*
Yield (t/ha)	ware	25.00	26.17	27.50
	seed	21.50	22.40	22.70
	starch	32.10	34.10	36.30
	early	14.50	17.44	19.00
Farmer prices (EUR/t)	ware	152.00	192.00	225.00
	seed	272.00	291.00	305.00
	starch	65.00	69.00	76.00
	early	160.00	176.00	193.00
Total costs (EUR/ha)	ware	4 627.00	4 559.00	4 470.00
	seed	4 551.00	4 463.00	4 352.00
	starch	3 393.00	3 327.00	3 244.00
	early	3 360.00	3 165.00	2 831.00

PE – pessimistic estimate; *ML* – most likely estimate; *O* – optimistic estimate; ware – ware potatoes; seed – seed potatoes; starch – potatoes for starch production; early – early potatoes

Source: authors' calculations

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Table 3. Average farmer prices of potatoes (EUR/t)

Utility type	Year									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ware	134	125	244	102	158	269	120	238	169	168
Seed	255	248	279	229	244	305	247	319	292	276
Starch	71	65	55	54	64	87	66	62	73	68
Early	176	139	164	160	139	214	153	179	193	175

ware – ware potatoes; seed – seed potatoes; starch – potatoes for starch production; early – early potatoes

Source: CSO (2018), PRI HB (2018)

Table 4. Total costs of potatoes (EUR/ha)

Utility type	Year									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ware	3 416	3 433	3 669	3 787	4 215	4 550	4 621	4 506	4 355	4 471
Seed	3 410	3 427	3 664	3 781	4 209	4 543	4 614	4 498	4 348	4 464
Starch	2 542	2 554	2 730	2 818	3 137	3 386	3 439	3 353	3 241	3 327
Early	2 635	2 649	2 831	2 922	3 252	3 511	3 565	3 476	3 360	3 449

ware – ware potatoes; seed – seed potatoes; starch – potatoes for starch production; early – early potatoes

Source: IAEI (2018)

10 and 5 (10/5) years was as follows: 172.7/192.8 EUR/t for ware potatoes; 269.4/287.8 EUR/t for seed potatoes; 66.5/71.2 EUR/t for starch potatoes and 169.2/182.8 EUR/t for early potatoes.

Given the significant upward trend, marginal conditions were set based on data collected over the past 5 years (Table 3). By analysing these data, the marginal conditions for the triangular statistical distribution, according to Table 2 were considered.

Total costs. The total costs are analysed based on the Institute of Agricultural Economics and Information monitoring system (IAEI 2018; Table 4).

Table 5. Market production with subsidies (*MPS*) (EUR/ha)

Utility type		Year									
		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ware	*MP*	3 417	3 200	5 661	2 938	4 329	5 810	3 228	5 165	5 019	5 174
	SY	179	194	186	189	234	246	225	408	389	391
	MPS	3 596	3 394	5 847	3 127	4 563	6 056	3 453	5 573	5 408	5 565
Seed	*MP*	5 432	5 729	6 361	5 450	5 710	5 917	5 311	5 774	6 950	6 293
	SY	179	194	186	189	234	246	225	408	389	391
	MPS	5 611	5 923	6 547	5 639	5 944	6 163	5 536	6 182	7 339	6 684
Starch	*MP*	2 293	2 028	1 667	2 581	2 138	2 871	2 534	1 352	2 759	2 455
	SY	877	840	748	744	1 474	1 295	1 472	614	700	631
	MPS	3 170	2 868	2 415	3 325	3 612	4 166	4 006	1 966	3 459	3 086
Early	*MP*	2 884	2 417	2 758	2 773	2 331	3 094	2 908	3 096	4 087	3 109
	SY	179	195	186	190	235	244	225	408	389	391
	MPS	3 063	2 612	2 944	2 963	2 564	3 340	3 133	3 504	4 476	3 500

ware – ware potatoes; seed – seed potatoes; starch – potatoes for starch production; early – early potatoes; *MP* – market production without subsidies; *SY* – subsidy (SAPS + voluntary support coupled to production); SAPS – Single Area Payment Scheme

Source: PRI HB (2018), IAEI (2018) and authors' calculations

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Table 6. Gross profit (*GP*) of potatoes growing with subsidies (EUR/ha)

Utility type		Year									
		2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ware	*MPS*	3 596	3 394	5 847	3 127	4 563	6 055	3 453	5 573	5 408	5 565
	TC	3 416	3 433	3 669	3 787	4 215	4 550	4 621	4 506	4 355	4 709
	GP	180	–39	2 178	–660	348	1 505	–1 168	1 067	1 053	856
Seed	*MPS*	5 611	5 923	6 547	5 640	5 943	6 163	5 535	6 182	7 339	6 684
	TC	3 410	3 427	3 664	3 781	4 209	4 543	4 614	4 498	4 348	4 464
	GP	2 201	2 496	2 883	1 859	1 734	1 620	921	1 684	2 991	2 220
Starch	*MPS*	3 170	2 868	2 415	3 325	3 612	4 166	4 007	1 965	3 460	3 086
	TC	2 542	2 554	2 730	2 818	3 137	3 386	3 439	3 353	3 241	3 327
	GP	628	314	–315	507	475	780	568	–1 388	219	–241
Early	*MPS*	3 063	2 612	2 944	2 963	2 564	3 340	3 133	3 503	4 476	3 501
	TC	2 635	2 649	2 831	2 922	3 252	3 511	3 565	3 476	3 360	3 449
	GP	428	–37	113	41	–688	–171	–432	27	1 116	52

ware – ware potatoes; seed – seed potatoes; starch – potatoes for starch production; early – early potatoes; *MPS* – market production with subsidies; *TC* – total costs

Source: authors' calculations

The value of costs shows an increasing tendency, which corresponds to the development of input prices and adherence to technological discipline.

The average total cost of the last 10 and 5 (10/5) years was as follows: 4 102/4 500 EUR/t for ware potatoes; 4 096/4 493 EUR/t for seed potatoes; 3 053/3 349 EUR/t for starch potatoes and 3 165/3 472 EUR/t for early potatoes. In view of the significant upward trend, marginal conditions were set on the basis of the data collected during the last 5 years (Table 2).

Market production. The results of the market production calculations according to the market orientation of the potatoes are depicted in Tables 2 and 5. The resulting values are calculated by multiplying the relevant input parameters according to Relation 1. The SAPS (Single Area Payment Scheme) subsidies plus voluntary support coupled to production were included in the market output (Table 5).

Gross profit. The results of the gross profit calculations are shown in Table 6. The resulting values are calculated by multiplying the relevant input parameters according to Relation 2. The table depicts a comprehensive view of the situation in the area of the market economy of potatoes growing.

Table 7 displays a qualified estimate of the gross profit.

Table 7. Qualified estimate of the gross profit (EUR/ha)

Utility type	Gross profit
Ware	992
Seed	1 841
Starch	182
Early	–31

ware – ware potatoes; seed – seed potatoes; starch – potatoes for starch production; early – early potatoes

Source: authors' calculations

RESULTS AND DISCUSSION

By entering the input parameters into the model, the results of gross profit for all seed potatoes are displayed in Table 8. The interpretation is established by considering the statistical evaluation of the computed values.

Profitability of seed potatoes. The probability of reaching gross profit that was established by performing a qualified estimate (1 841 EUR/ha) can be expected with a risk of 68.03%. There is 31.97% probability of exceeding this value. Additional risk values for further estimates of gross profit are shown in Table 9.

Ware potatoes. The probability of reaching a gross profit that was established by performing a qualified estimate (992 EUR/ha) can be expected with a risk of 53.01%. There is a 46.99% probability of exceeding this value. Reaching a break-even point can be expected with the risk of 0.38%. There is a

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Table 8. Statistical processing of risk situations concerning the gross profit of utility type

Statistics	Early	Seed	Starch	Ware
Trials		100 000		
Base case	–31.00	1 841.00	182.00	992.00
Mean	–59.69	1 753.32	226.50	948.96
Median	–56.75	1 758.34	222.53	959.10
Standard deviation	228.46	172.11	102.90	404.05
Variance	52 194.76	29 623.42	10 587.73	163 254.81
Skewness	–0.0200	–0.1107	0.1686	–0.0614
Kurtosis	2.74	2.63	2.76	2.47
Coefficient of variation	–3.8300	0.0982	0.4543	0.4258
Minimum	–841.61	1 140.28	–111.18	–218.59
Maximum	785.25	2 300.29	599.58	2 127.91
Range width	1 626.87	1 160.00	710.76	2 346.49
Mean std. error	0.72	0.54	0.33	1.28

early – early potatoes; seed – seed potatoes; starch – potatoes for starch production; ware – ware potatoes

Source: authors' calculations

99.62% probability of exceeding this value. Additional risk values for further estimates of gross profit are given in Table 10.

Starch potatoes. The probability of reaching gross profit, which was established by a qualified estimate (182 EUR/ha) can be expected with the risk of 34.76%. There is 65.26% probability of exceeding this value. Reaching a break-even point can be expected with the risk of 0.76%. There is 99.24% probability of exceeding this value. Risk values for further estimates of gross profit are given in Table 11.

Early potatoes. The probability of reaching gross profit that was established by performing a qualified estimate (–31 EUR/ha) can be expected with a risk of 54.52%. There is 45.48% probability of exceeding this value. Reaching a break-even point can be expected with the risk of 59.80%. There is a 40.20% probability of exceeding this value. Risk values for further estimates of gross profit are given in Table 12.

Overlay chart in Figure 1 shows the frequency distribution of a gross profit minimum for the individual seed of potatoes and generated random variables together with the probability of achieving them. As it is apparent from the graph, starch potatoes perform the maximum value of the probability of achieving a gross profit of 12.06% and reaches the third lowest value of the gross profit. The ware potatoes reach the lowest value of the probability of achieving a gross profit. 3.1% but this variety also achieves the second highest value of the gross profit. The analysis of the sensitivity of the individual seed

Table 9. Overview of the risk values for planned gross profit – seed potatoes

Planned gross profit (EUR/ha)	Risk of gross profit (%)
1 200	0.01
1 500	7.87
1 800	59.20
2 100	98.45
2 200	99.90

Source: authors' calculations

Table 10. Overview of the risk values for planned gross profit – ware potatoes

Planned gross profit (EUR/ha)	Risk of gross profit (%)
0	0.38
500	14.99
1 000	53.93
1 500	90.80
2 000	99.96

Source: authors' calculations

Table 11. Overview of the risk values for planned gross profit – starch potatoes

Planned gross profit (EUR/ha)	Risk of gross profit (%)
0	0.76
100	10.95
200	41.47
300	76.07
400	94.72

Source: authors' calculations

Table 12. Overview of the risk values for planned gross profit – early potatoes

Planned gross profit (EUR/ha)	Risk of gross profit (%)
–500	2.71
–250	20.90
0	59.80
250	91.16
500	99.52

Source: authors' calculations

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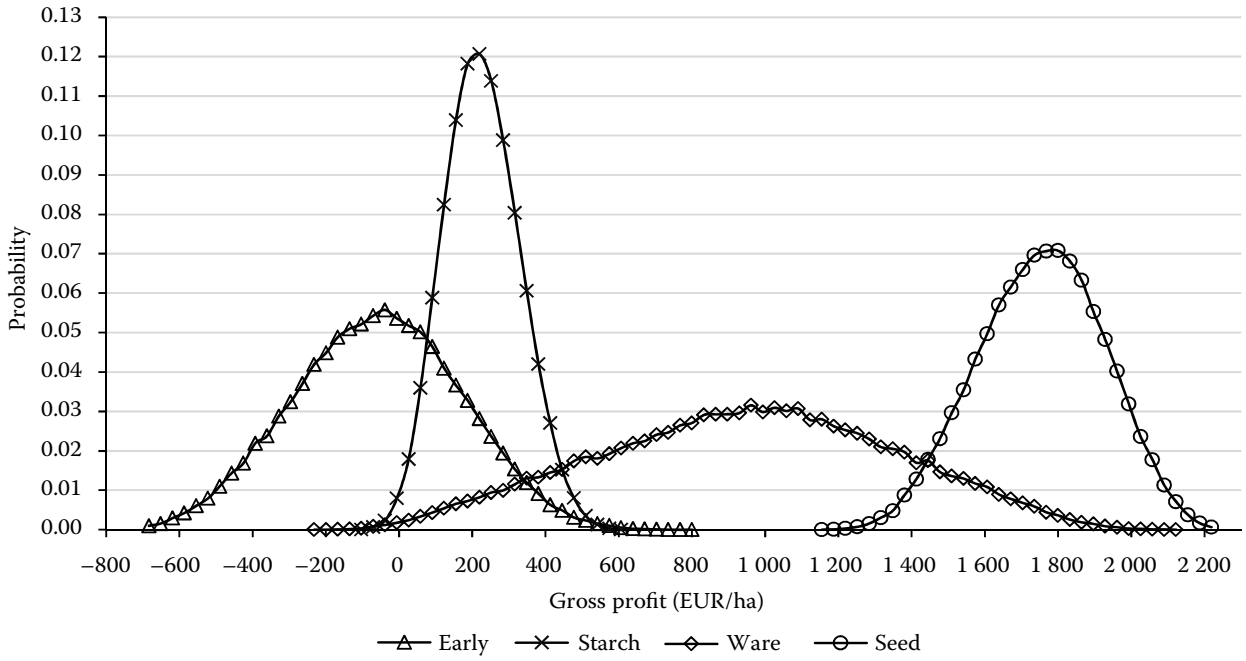

Figure 1. Distribution curves and probability of achieving gross profit of utility type

early – early potatoes; starch – potatoes for starch production; ware – ware potatoes; seed – seed potatoes

Source: authors' calculations

of potato showed that the greatest impact on achieving gross profit has the farmers price (its influence ranged from 25 to 94.3%), followed by potatoes yield (their influence ranged from 5.1 to 53%) and overall costs (their effect ranged from 8 to 22%).

CONCLUSION

The utility type can also be compared on the basis of the rules of mean value and variance. The highest mean value and the second smallest variance belongs to the seed potatoes. Second highest mean value but the highest variance at the same time belongs to the ware potatoes. Third highest mean value but the lowest variance belongs to the starch potatoes. Early potatoes achieved a negative mean value and the second highest variance value. To put it in a nutshell, early potatoes are the riskiest variety for growing.

For the assessment of the gross profit, we can, therefore, use the stochastic dominance rule, which evaluates the entire probability distribution of selected criteria, and not just some of its features. According to the first rule of stochastic dominance, such a variant is preferred, in which the value of the distribution function at each point reaches higher values than the value of function for non-preferred option. Figure 2 shows graphs of cumulative distribution function values and their mutual overlap. The graph shows that the distribution function of the seed potatoes is on the right of the cumulative frequency graph for distribution functions of the ware potatoes, which lies to the right of the cumulative frequencies graph for the starch potatoes. Most to the left side lies the cumulative frequencies graph for the early potatoes. From this, we can deduce that the distribution value of seed potatoes is smaller for any value of the gross profit, or equal, corresponding to the value of the distribution function of the ware potatoes. The seed potatoes stochastically dominate the ware potatoes, regardless of risk. The ware potatoes stochastically dominate the starch potatoes. The starch potatoes stochastically dominate the early potatoes. Therefore, for the above reasons, it is no longer necessary to access the application of the second rule of stochastic dominance. In terms of risk of reaching the required gross profit, the best and most profitable are the seed potatoes, followed by the ware potatoes, followed next by the starch potatoes and the last place take the early potatoes, which also have the third highest probability of achieving the gross profit. However, it is necessary to closely monitor the development of individual risk factors, particularly the farmer's price and

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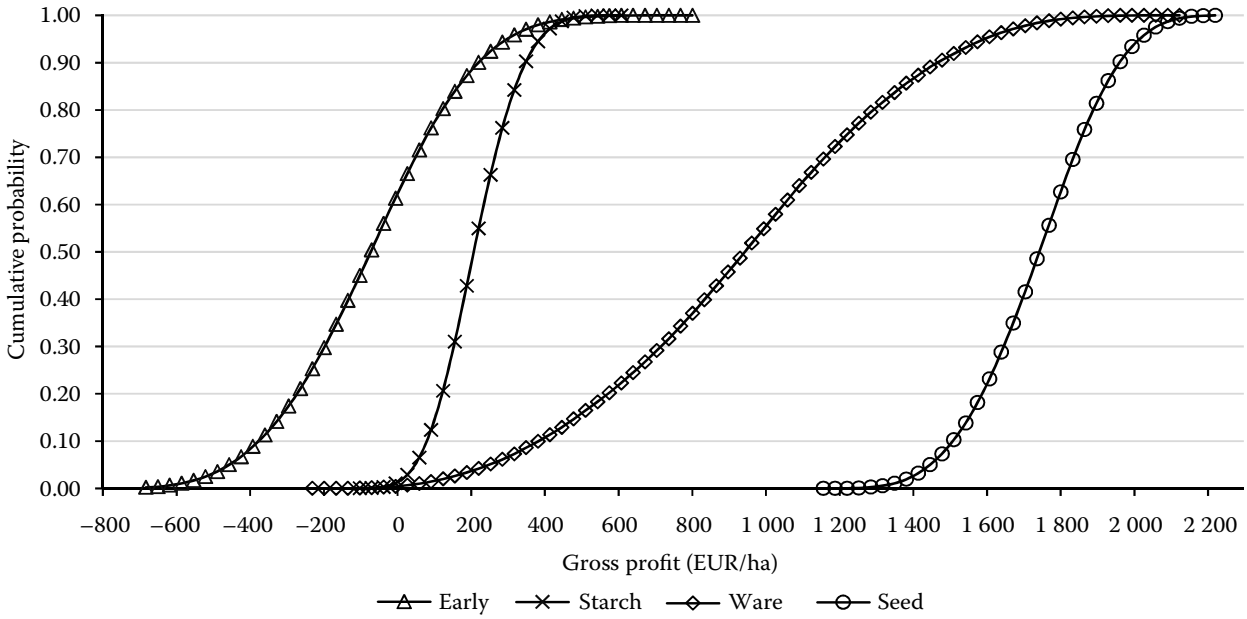

Figure 2. Cumulative frequency of gross profit probability distribution

early – early potatoes; starch – potatoes for starch production; ware – ware potatoes; seed – seed potatoes

Source: authors' calculations

the yield. In the event that their development would significantly deviate from the values used for this analysis, it might be necessary and recommendable to re-analyse the risks based on changed conditions. Growing the early potatoes in the current conditions in the Czech Republic can, therefore, be generally classified as risky.

Table 13 lists predicted values of achieving a gross profit for each utility type considering different values of the probability in increments of 10%. From this table, it can be determined to a specific degree of probability which values of the gross profit will be achieved in individual utility type.

Table 13. The probability of achieving these gross profit values concerning utility type (EUR/ha)

Percentiles (%)	Early	Seed	Starch	Ware
100	–841.61	1 140.28	–111.18	–218.59
90	–361.74	1 523.08	95.09	398.80
80	–256.95	1 602.42	137.00	586.30
70	–181.97	1 661.26	168.42	730.90
60	–117.38	1 711.84	196.16	849.79
50	–56.75	1 758.34	222.53	959.10
40	1.57	1 803.78	249.80	1 063.87
30	64.30	1 850.80	279.67	1 176.07
20	137.08	1 904.28	314.64	1 307.58
10	235.55	1 975.63	363.34	1 481.09
0	785.25	2 300.29	599.58	2 127.91

Source: authors' calculations

It is possible to draw the following results and recommendations from the analysis of the economic risks of potatoes growing: when planning gross profit from growing market crops, the risk of not obtaining the planned results must be taken into account. Generally, the higher the planned gross profit, the higher the risk of not fulfilling the appointed target. When interpreting the risk in plant production, it is possible to use the classification where the risk amounting to 20% is ranked as low, 21–40% as acceptable, 41–60% as high and above 60% as very high (thus unacceptable).

It was proven that regarding potatoes growing, there is a very high risk of not obtaining the expected gross profit for the varieties of early potatoes, starch [a similar result for starch potatoes was reported by Dobele and Vitols (2016)] and ware potatoes. In this context, the high-risk seed is the one of early potatoes. On the other hand, seed potatoes give the best results. Growing potatoes in the conditions of the Czech Republic and without subsidies is from the economic point of view, unfortunately, a very problematic undertaking. This also becomes notice-

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able and obvious from the progressively decreasing areas of potatoes cultivation and then subsequently the increasing amount of potatoes imported to us from other countries.

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