QUANTIFYING SYSTEMIC AND IDIOSYNCRATIC RISKS IN AGRICULTURE: A STUDY OF KAZAKHSTAN'S GRAIN PRODUCTION VOLATILITY

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ABSTRACT

This article proposes a method for quantifying the impact of idiosyncratic and systemic risks on agricultural production volatility and developing techniques and procedures for calculating the number of losses due to systemic risks. The analysis is based on grain yield and price data adjusted for inflation, trends, and acreage in the northern grain-producing region of Kazakhstan from 2005 to 2017. This study presents a method for determining the proportion of systemic and idiosyncratic risk in variations in agricultural production volume. Using a method based on the beta factor can significantly reduce subjectivism and prevent exploitation when assessing and compensating farmers for damages resulting from adverse natural phenomena. The authors believe this is the first study to examine the impact of systemic and idiosyncratic risks on the volatility of production volumes in the grain industry under specific economic conditions in emerging markets.

Keywords: agriculture; grain production; systemic risk; idiosyncratic risk; economic loss

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INTRODUCTION

Historically, Kazakhstan has been an agricultural country where risky business properties are most obvious. The fact remains that in Northern Kazakhstan grain farms, about 80 per cent of the variation in wheat yield is determined by the variation of hydrothermal conditions (Bokusheva et al., 2007). In spite of the fact that agro-industrial insurance is one of the instruments employed to regulate agro-industrial production based on market principles and World Trade Organization (WTO) agreements, agricultural entrepreneurship is characterised by systemic risks that cannot be insured through market mechanisms (World Trade Organization. Agreement on Agriculture, Annex 2, 1995). Systemic risk is considered the most dangerous since it can potentially result in the bankruptcy of economic entities (Mason et al., 2003). The reinsurance market cannot provide sufficient protection against systemic risk since it is based on the same principles as the primary insurance market (Bokusheva et al., 2007; Miranda and Glauber, 1997).

The high proportion of systemic risk in grain production in Kazakhstan casts doubt on the feasibility of developing an insurance business in the region's agriculture without the participation of the government. On the other hand, state subsidisation of expenses for compensation of damage from risk without a clear distinction between systemic and individual risks is potentially fraught with the possibility of abuse and the actual transfer of the entire burden of responsibility, including for diversified risk (which can and should be managed exclusively by market forces), to the state budget. Therefore, identifying damage caused by systemic and only systemic risk is paramount to determine to what extent the state can participate in the compensation of damage incurred by agriculture due to the increased unpredictability of economic conditions due to climate change.

LITERATURE REVIEW

Extreme fluctuations in daily temperatures and changes in precipitation distributions generally have a negative impact on the agricultural sector. There are, however, studies that show an increase in temperature increases crop yields per hectare, especially in Nordic countries (King et al., 2018; Morel et al., 2021). The fact remains, however, that this is true not only for developing countries but also for developed countries. Analysis by Hoffman et al. (2018) shows that the increase in yield due to the introduction of new technologies can be negated due to the greater aridity of the climate. Many authors are interested not only in the quantitative assessment of climatic impacts but also in the influence of technical and economic factors on the yield of the main crops in the sown area, and the omission of this aspect can also lead to overestimated or underestimated results (Füssel, 2007).

Weersink et al. (2010) indicate a fairly close relationship between the size and structure of acreage on the one hand, and weather conditions, crop yields and prices on the other. This circumstance is important in the analysis of the problem of agriculture adaptation to climate change.

Changes or spatial shifts in land use will occur increasingly as a result of the adaptation of agriculture to climate change (Yasmin et al., 2022). Furthermore, agriculture can potentially affect the climate through its emissions and runoff. In order to assess the climatic sensitivity of Kazakhstan's agriculture, two key factors should be considered: a significant change in the size and structure of land use and the technical re-equipment of the sector. Qualitative and quantitative parameters of the technical equipment of the industry and the technologies used affect the nature of volatility in crop yields very significantly (Conradt et al., 2014; Bokusheva et al., 2012).

Agricultural entrepreneurship is characterised by so-called systemic risks, which market mechanisms cannot insure. Furthermore, agribusiness's riskiness is only increasing due to climate change. Compared to current levels in Kazakhstan, spring wheat yields are expected to decrease by 13-37% by 2030 and 20-49% by 2050. This is due to a decrease in moisture supply during the growing season, an increase in droughts and dry periods, and a decline in pasture capacity (Kazakhstan may suffer economic losses in wheat production due to climate change, 2020). Kazakhstan experienced a drought and lack of feed in 2021, which led to a state of emergency being declared for the first time in a number of areas. In order to eliminate the consequences of this incident, the country has allocated more than 2 billion tenge from its budget. The EU provided 200 thousand euros as humanitarian assistance, which was received by approximately 6 thousand people in the affected regions of Kazakhstan (The EU allocated 200 thousand euros to drought victims in Mangistau and Turkestan regions, 2021).

It is estimated that about 60% of the insured areas in Kazakhstan are comprised of areas with yields ranging from ten quintals to ten quintals per hectare and coefficients of variation between 30 and 55%. Thus, with fixed tariffs, insurance policies are typically purchased by economic agents with a higher level of risk. It should be noted that most of the government's subsidies are devoted to crop insurance premiums. Since

2022, the subsidised portion of the premium has been increased from 50% to 80%.

Systemic risks predetermine the participation of the state in agricultural insurance. At the same time, there is an objective danger of unjustifiably shifting all responsibility for compensating farmers' losses to the state budget. To avoid such a danger, it is necessary to clearly distinguish the impact of systemic and idiosyncratic risks on the results of agricultural business.

A methodology for assessing systemic risk described by Kussaiynov (Kussaiynov, 2017) involves calculating the ratio of the variability of the production volume in the whole system to its variability, calculated under the hypothetical assumption that fluctuations in production volume in the subsystems are mutually independent. And the results achieved with the use of the methodology depend on the hierarchical structure of the system and the degree of integration of the data used in the analysis. For example, if we consider the North-Kazakhstan regionas a system and consider rays as subsystems, then the share of systemic risk in the grain production of the region will be about 56.6% of the total risk. Accordingly, the share of diversified risk will be 43.4%. If we consider the northern grain-growing region of Kazakhstan as a system, and the Akmola, Kostanay and North Kazakhstan regions included in it as subsystems, then the share of systemic risk amounts to about 40% of the total risk. It should be noted that the methodology gives only a general idea of the presence and size of systemic risk in the entire region. For practical purposes, the quantitative assessment of the impact of systemic risk on output volume variability in subsystems that make up an entire territorial economic system is much more useful and informative. This formulation of the question is explained by the fact that agricultural production is carried out, as a rule, in open space and vast territories, especially in Kazakhstan. It is worth noting that the natural and economic conditions of management are very different, even within the borders of one region.

METHODOLOGY

Developing a methodology for assessing the impact of systemic risk on agricultural production volumes can be aided by referring to concepts used in risk analysis on financial markets, specifically the beta coefficient.

In the analysis of financial market dynamics, the beta coefficient is used for assessing non-diversified systemic risk. Finance theory refers to systemic risk as a market risk because it reflects the processes of the market system as a whole (Gitman and Joehnk, 2001; Vose, 2000). The beta factor represents how the security rate reacts to market forces: the higher the beta coefficient of security, the more affected it is by general market processes (changes in market behaviour as a whole). By analogy, in the agricultural market, the beta coefficient will indicate to what extent the volume of production per hectare of crops in a particular farm "depends" on the same indicator in the entire region (or how productivity changes between a specific farm or area and the regional average productivity). In the agricultural market, the beta coefficient of regional productivity is assumed to be equal to one, and beta coefficients for each individual district (farm) within the region are calculated in relation to this coefficient. Table 1 interprets some values of the factor "beta" with respect to crop yields.

For a farm, the beta factor can be useful in assessing systemic risk and understanding the type of reaction of agricultural productivity in a particular farm to the risk of a systemic nature. For a farm with a positive beta value, an increase in productivity in the whole region means an increase in productivity in this particular area. However, a decrease in regional productivity means a decrease in productivity on the farm. If the beta is negative, the relationship between farm productivity and regional productivity is inverse.

The “beta” factor can be measured using a regression equation with a beta coefficient:

$$y_t = \alpha + (\beta \times y_{rt}), \quad (1)$$

where $y_t -$ farm (subsystem) productivity in year t; $\alpha -$ intercept; $\beta -$ “beta” coefficient; $y_{rt} -$ regional (system) productivity in year t.

Table 1: Interpretation of the "beta" factor values in relation to crop yields.

"beta" factor	Comments	Interpretation
2,0	Changes in the same direction as the regional yield	2 times more responsive than regional yields
1,0	Changes in the same direction as the regional yield	It is just as risky as at the regional level
0,5	Changes in the same direction as the regional yield	Twice less responsive than in the region
0	The yield at the enterprise is not related to the yield by region	Does not depend on regional conditions
-0,5	Changes in the opposite direction than the regional yield	It is half as responsive as at the regional level
-1,0	Changes in the opposite direction than the regional yield	It is just as risky as at the regional level
-2,0	Changes in the opposite direction than the regional yield	Twice as responsive as in the region

Source: author's work

The coefficient of determination obtained by using equation (1) measures the explanatory power of the regression model. It can be interpreted as the share of the systemic component of risk in the total risk, which is expressed in fluctuations in productivity. Accordingly, the difference between 1 and the value of the coefficient of determination represents the share of idiosyncratic (diversifiable) risk in the total risk.

A matrix of spring wheat production volumes per hectare for the period 2005 to 2017 has been developed (Table 2) using data on grain yields and prices adjusted for trends and inflation, along with crop sowing areas of the North Kazakhstan region.

A beta parameter has been used to assess the damage caused to agricultural entrepreneurs solely by systemic risk. The loss of production in the economic system due to systemic risk has been calculated according to the formula:

$$\Delta_i = \beta_i \times (y_e - y_a), \quad (2)$$

where β_i is the "beta" coefficient of the production volume per one hectare on farm i ; y_e is the expected regional production volume and y_a is the actual regional production volume in the year under review.

Table 2: Volume of production per hectare by rayons of the North-Kazakhstan region from 2005 to 2017, thousand tenge/ha (adjusted for inflation)

Year	Rayon													North-Kazakstan region
	Aiyrtau	Akzhar	Aqqaiyn	Essil	Jambyl	Magzhan Jumabayev	Qyzyljar	Mamlut	Gabit Musrepov	Taiynsha	Timiryazev	Ualikhanov	Shalaqyn	
2005	30,8	32,9	35,5	33,5	25,1	29,9	33,4	28,1	29,4	37,3	26,0	28,5	35,2	31,4
2006	38,7	29,3	50,3	49,8	43,4	39,0	40,5	41,3	43,5	45,7	54,8	29,7	41,2	42,1
2007	58,9	51,7	72,2	61,5	80,6	47,5	60,3	66,8	73,6	76,6	67,1	82,8	79,8	67,8
2008	57,8	27,9	74,6	66,4	65,1	83,5	73,3	62,6	69,6	67,2	0,0	0,0	52,6	57,7
2009	43,7	32,7	73,2	46,4	47,3	76,6	77,4	53,0	54,4	60,1	53,5	68,1	47,3	55,2
2010	64,4	43,8	51,5	40,8	43,0	58,6	66,0	65,0	37,0	40,3	42,5	62,4	44,0	48,1
2011	73,8	33,8	73,3	66,9	71,3	69,0	83,1	56,0	79,9	62,0	73,7	42,8	45,6	64,6
2012	72,0	28,9	59,3	57,3	59,4	58,8	71,5	61,6	40,2	38,3	52,9	29,8	37,0	48,2
2013	43,2	17,6	39,8	36,1	33,2	49,8	45,0	36,1	46,0	40,0	27,6	25,1	28,0	37,2
2014	41,7	25,2	43,4	36,3	36,8	52,7	45,9	39,5	53,3	40,7	35,2	29,7	29,0	40,8
2015	37,2	23,3	29,8	33,9	34,3	46,8	43,9	35,6	45,4	30,6	36,8	45,6	24,1	36,7
2016	30,3	15,4	47,2	42,2	43,1	41,9	42,1	44,5	49,6	28,7	42,9	34,1	41,0	38,4
2017	40,3	33,1	51,5	45,5	41,6	43,6	40,4	45,9	44,8	29,2	48,4	21,7	42,8	40,7

Source: author's work

A calculation of the risk shares of systemic and idiosyncratic components in the total risk (by rays of North-Kazakhstan) is presented in the two last columns of Table 3.

Table 3: Assessment of systemic and idiosyncratic risks by rayons of North-Kazakhstan region

No.	Rayon	The share of systemic risk (R^2)	The share of idiosyncratic risk ($1-R^2$)	"beta" coefficient
1	Aiyrtau	0,53	0,47	0,91
2	Akzhar	0,33	0,67	0,47
3	Aqqaiyn	0,87	0,13	1,20
4	Essil	0,79	0,21	0,89
5	Zhambyl	0,88	0,12	1,28
6	Magzhan Zhumabayev	0,51	0,49	0,91
7	Qyzylzhar	0,69	0,31	1,17
8	Mamlut	0,71	0,29	0,89
9	Gabit Musrepov	0,72	0,28	1,05
10	Taiynsha	0,82	0,18	1,17
11	Timiryazev	0,83	0,17	1,19
12	Ualikhanov	0,50	0,50	1,11
13	Shalaqyn	0,62	0,38	0,92
14	North-Kazakhstan region	1,00	0,00	1,00

Source: author's work

Table 4 shows an example of calculating losses due to systemic risk in wheat production (by rayons of the North-Kazakhstan region).

Table 4: Assessment of losses due to systemic risk in the rayons of North-Kazakhstan region (data for 2017 are taken as the actual production volume)

No.	Rayon	Actual production volume, thousand tenge per ha	"beta" coefficient	Loss, thousand tenges per ha
1	Aiyrtau	40,326	0,91	-3,182
2	Akzhar	33,106	0,47	-1,626
3	Aqqaiyn	51,456	1,20	-4,189
4	Essil	45,467	0,89	-3,116
5	Zhambyl	41,565	1,28	-4,466
6	Magzhan Zhumabayev	43,596	0,91	-3,178
7	Qyzylzhar	40,434	1,17	-4,071
8	Mamlut	45,914	0,89	-3,119
9	Gabit Musrepov	44,778	1,05	-3,673
10	Taiynsha	29,187	1,17	-4,104
11	Timiryazev	48,351	1,19	-4,173
12	Ualikhanov	21,700	1,11	-3,869
13	Shalaqyn	42,828	0,92	-3,215
14	North-Kazakhstan region	40,694	1,00	-3,493

Source: author's work

In scenarios where an insured event occurs, the above methodology can be used to accurately determine the amount of state participation in compensation for farm losses. Using the example provided, the last column of the table shows the amount of compensation per hectare for damage. As an example, the government must compensate farms in the Aiyrtau rayon for a loss of 3182 tenges per hectare of wheat. The average damage from systemic risk is expected to be 3869 tenge per hectare in the region. The example shows how the size of the state's compensation for damage is calculated under the assumption that it will be obliged to cover losses in full. Assuming that the state will only compensate a certain percentage of the damage (for example, 75%), the results should be multiplied by the appropriate coefficient.

DISCUSSION

The following two remarks should be borne in mind: (1) $y_e \succ y_a$ for $\beta_i \succ 0$, (2) $y_e \prec y_a$ for $\beta_i \prec 0$. The first remark means that on a farm where the volume of production changes in the same direction as in the region (that is, the "beta" factor is positive), damage occurs only when the actual volume of production in the region is lower than expected. The second remark refers to cases where the beta factor is negative; that is, the directions of change on the farm and in the region are opposite. Then, the damage on the farm occurs when the actual regional production volume is higher than the expected one. If the state assumes the corresponding obligations, then it must compensate the farm for damages resulting from systemic risks (to the extent of 100 per cent coverage). Consequently, this methodology minimises the possibility of subjectivism and abuse when determining the loss and the amount of compensation provided by the state.

Kazakhstan had a law on compulsory insurance in crop production that had been in effect for almost 15 years (On compulsory insurance in crop production, 2004). This law stipulated that the government annually established insurance tariff sizes by regions without providing additional information at the rayon level or mentioning any business entities. It has resulted in farms that are currently operating successfully becoming a source of financing for farms that are underperforming. It is not surprising that advanced farms were forced to participate in insurance due to their mandatory nature; furthermore, they were insured at the lowest possible rates, believing that, in any event, they would not have received any insurance benefits. Therefore, the mandatory form of agricultural insurance has largely lost its stimulating functions and, in a certain sense, has begun to cultivate a dependency culture among agricultural entrepreneurs. There has been no longer a requirement for crop insurance in crop production since 2020.

Simply stated, state subsidisation of expenses for compensation of damage from unfavourable economic conditions without a clear distinction between systemic and idiosyncratic risks is potentially fraught with the possibility of abuse and the actual transfer of the entire burden of responsibility, including for the idiosyncratic risk (which can and should be managed exclusively by market forces) to the state budget.

CONCLUSION AND RECOMMENDATION

Failure to comply with insurance principles inevitably leads to insurance programs becoming so-called "market mechanisms" for subsidising the industry and cultivating dependency among agricultural entrepreneurs. The high level of systemic risk in grain production in Kazakhstan's main grain-growing regions casts doubt on the possibility of developing crop insurance without state participation.

State subsidisation of expenses for compensation of damage from risk without a clear distinction between systemic and individual risks is potentially fraught with the possibility of abuse and the actual transfer of the entire burden of responsibility, including for diversifiable risk (which can and should be managed exclusively by market mechanisms), to the state budget and other public funds. Therefore, the identification of damage caused by systemic and only systemic risk is of paramount importance to determine to what extent the state should participate in compensation for losses caused to agriculture by adverse natural phenomena. The calculation method based on the beta factor can significantly reduce subjectivism and avoid abuse in assessing and compensating farmers for damage from unforeseen natural events.

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