Efficiency of Selected Risk Management Instruments – an Empirical Analysis of Risk Reduction in Kazakhstani Crop Production

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EFFICIENCY OF SELECTED RISK MANAGEMENT INSTRUMENTS – AN EMPIRICAL ANALYSIS OF RISK REDUCTION IN KAZAKHSTANI CROP PRODUCTION

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ABSTRACT

Recent academic discussion regarding crop insurance in developing and transition countries has focused on weather index insurance. But empirical analyses of such schemes based on farm level data cannot be found in the literature, though this insurance type shows clear advantages compared to multiple-peril crop insurance and revenue insurance.

Recent empirical applications of risk and stochastic programming models focus on the optimisation of production planning, while literature on the effects of crop insurance on the farm level mainly focuses on the empirical investigation of reductions in farm income variance.

The novelty of this paper is that it integrates regionally-adapted insurance products and expert-evaluated technology choices into a programming model that analyses activities with regard to their utility-efficiency.

Thus, the objective of this paper is to analyse the effects of different risk management instruments on the certainty equivalent of case study farms in three different regions. Specifically, the applied Expected Utility Model analyses on-farm risk management instruments and crop insurance products with regard to their capability of stabilising farm income.

Results indicate that only a combination of on-farm and financial risk management measures increases income and efficiently reduces risk. Weather-based insurance, in combination with intensive technology, stabilises income most efficiently in a specialised grain region whereas farm-yield insurance combined with an extensive technology is the preferred risk management option in East Kazakhstan, where diversification with oil-producing crops is possible.

1 INTRODUCTION

After structural change, which was connected to the privatisation of agricultural enterprises, production risk became a significant economic burden for Kazakhstan's agricultural sector. Post Soviet Union countries, including the Republic of Kazakhstan, have distinctly reduced their role as a back-up financier of production losses related to risk. Newly evolved enterprises inevitably have to adapt to natural conditions, the existing political framework and the business environment. Specifically, farmers have to find strategies to manage risk caused by natural hazards and market conditions.

A variety of risk management measures is available to farmers, the practical use of which depend on a number of factors. Besides the political and market framework, enterprise-inherent factors, such as liquidity, the decision-maker's experience with specific risk management measures and his attitude toward risk all influence their application.

Recent academic discussion regarding crop insurance in developing and transition countries has focused on weather-based insurance schemes (Anderson, J. R.; Skees, Hazell, and Miranda; Varangis, Skees, and Barnett; OECD). But empirical analyses of weather index insurance schemes based on farm level data cannot be found in the literature, though this insurance type shows clear advantages[1] compared to multiple-peril crop insurance and revenue insurance.

The novelty of this paper is to integrate regionally-adapted insurance products and expert-evaluated technology choices into a programming model that analyses activities with regard to their utility-efficiency.

Thus, the objective of this paper is to analyse the effects of different risk management instruments on the certainty equivalent of study farms in two different regions. Specifically, the applied expected utility model analyses on-farm risk management instruments and crop insurance products with regard to their capability of stabilising farm income. From a practical viewpoint, results will provide decision-making support to farm managers who need to develop long-term technological solutions for stabilising crop yields and thereby farm income. From a political perspective, results may support the process of establishing a sound agricultural risk management framework in Kazakhstan. Methodologically, the applied procedure provides a way to analyse the effects of farm-adapted risk management instruments.

The paper begins by reviewing the literature, then presents the decision model and the empirical methods of solving it. This is followed by a description of crop production in the investigated regions and the employed data culminating with a presentation of the empirical results and conclusions.

2 METHODOLOGY AND DATA

The analysis of risk management options includes several steps as depicted in figure 1. As a starting point, crop yield correlation is tested on different regional levels to evaluate the regional potential for simple hedging by portfolio selection. The estimation of correlations is based on yield data from the oblast, rayon and farm levels in two selected research regions for the time period 1980-2002. In a preceding paper (Bokusheva et al., 2005) a variety of insurance products were analysed regarding their capabilities of reducing variance of wheat production income (step 2). In a third step, case farms and parallelly regionally-adapted insurance products were selected for analysis. The insurance products were then integrated in a utility-efficient programming model (step 4), which accounts for farmers' risk aversion, the financial situation of the enterprise and access to credit. In a last step, the model analyses efficient combinations of risk-influencing technologies and insurance products.

[1] Weather index insurance shows a comparative advantage in reducing problems related to asymmetric information, which exist in transition and developing countries in particular (Bokusheva, 2004).

The following three subsections, respectively, specify the model's assumptions regarding farmers' behaviour and utility, describe study farms and regions, and introduce the integrated risk management instruments.

2.1 Behavioural and utility assumptions

Since Freund (1956) wrote his paper on introducing risk in a programming model, many alternative risk programming models have been developed. For our problem, given some knowledge about the shape of the utility function and risk aversion, the utility-efficient programming (UEP) approach (Patten et al., 1988) seems to be well-suited (Hardaker et al., 1991) because assumptions about the shape of the utility function and risk attitudes are made. Furthermore, it permits the incorporation of a number of different probability distributions.

For the discussed base model, both case decision-makers (DM) were classified as slightly risk averse. After testing several approaches to determine risk aversion coefficients empirically, we share the opinion of Hudson et al. (2005), that consistent measurement of risk attitudes is difficult to achieve. Based on a direct utility elicitation method (Anderson et al., 1977), one of the three case decision-makers were classified as risk-neutral. According to an alternative qualitative risk aversion tests, the other DM was considered to be risk-averse. The implications of these measurement will be tested in future research.

Expected utility provides a convenient way to represent risk preferences: its basic idea is that decision-makers maximise expected utility. When income increases, utility increases less than proportionately for risk-averse decision-makers. Hence, utility is an increasing but downward bending function of income. Expected utility estimates can be translated into certainty equivalents (CE), where CE is the inverse of the utility function and represents the monetary value a person would take to avoid a certain risk. Knowing certainty equivalent outcomes not only permits the ranking of risky alternatives, but also facilitates estimating risk premiums. CE simultaneously accounts for the probabilities of risky prospects and the preferences for the consequences (Anderson et al., 1977). Each production activity and application of risk management instruments may influence a decision-maker's expected utility. Examining CE is one approach to investigating the magnitude of this influence.

The risk programming model integrates the assumptions of expected utility theory in an objective function and constraints:

$$\max CE = \left[(1-r)E(U)\right]^{1/(1-r)}$$

where

CE =certainty equivalent,

r = absolute risk aversion coefficient,

$U = 1 - \exp(1-r)z$ [2]

subject to

Ax ≤ b, Cx-Iz =uf, and x ≥ = 0,

where A is a matrix of technical coefficients for all activities, b is a vector of capacities, x is a row vector of adjustable variables, C is a matrix of activity net revenues by state, I is an n by n identity matrix (a matrix with ones along the NW-SE diagonal and zero everywhere else), z is the annual net income in each state, u is a vector of ones, and f is fixed or overhead costs.

2.2 Data description

The value of the potentially achievable gross margins is subject to uncertainty. This uncertainty is accounted for by deriving information about distribution functions from past realisations of the random variable. Basically, extensive enterprise-specific data sets were used. As a result of political changes and the major restructuring of agricultural enterprises, the available historical data might lead to unrealistic assumptions about distributions. In such cases, taking expert advice might be justified in order to derive reliable distributions (Hardaker et al., 2004). In our case, we used a blend of sources, including expert judgement,

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[2] The variables are defined as follows: z is the annual net income of the enterprise, r is the coefficient of absolute risk aversion The utility function U(z) is positive $(U'(z) \succ 0)$, but decreasing $(U''(z) \prec 0)$. This function is characterised by decreasing absolute $r_a(z) = -U''(z)/U'(z) = r/z$ constant relative risk aversion $r_r(z) = z r_a(z) = r$.

farm survey results[3] and literature resources to derive information on costs, revenues and probabilities. Concretely, parameters like size, specialisation and own capital endowment were derived from farm survey results (Table 1), whereas the data on input and output of different technology solutions stem from the analysis of regional yield and weather data for the period 1980-2004, and expert judgements based on interviews with farmers, researchers and regional agricultural administration staff members. The main justification of deviation from a reliance on historical data alone is the significant change in agro-climatic and economic production conditions. The addition of expert advice provides the opportunity to integrate potential technologies that are not widely used, but adapted to regional conditions and thereby offer the potential to improve economic enterprise performance.

The decision support that will be given combines production alternatives including adequate technological recommendations (soil cultivation, fertilisation, and pest management) and advice regarding the use of financial risk management instruments.

2.3 Description of risk management instruments

On-farm risk management measures are captured by introducing different production technologies. The technologies display possible solutions to influence quantity and the variability of output. The assumptions about yields and yield distributions are based on a combination of long-term experimental data for region-specific production conditions and expert probability judgements (Ivannikov, 2005, Sagadievich, 2005). Input prices are based on current market prices, while output prices are taken from regional statistics from 2001-2004. The considered technologies are characterised by ploughing cultivation and fixed crop rotation systems, e.g. for the model farm in Akmolinskaya oblast the fallow is followed by two seasons planted with spring wheat and one season planted with spring barley. Tables 2-4 present a summary of the most distinctive features of the considered technologies. The

[3] More information can be found in Heidelbach et al. (2004).

technologies show differences regarding the quantity of fertiliser and herbicide input, the quantity of labour and fuel input (which are mainly determined by the kind and frequency of soil cultivation) and the way soil humidity generation is accomplished. All of these technology features are reflected in the volume of total variable costs, which vary significantly among technologies. The technological differences result in intensely varying yield levels in different states of nature[4].

A holistic approach to risk management requires investigation into the effects of financial risk management alternatives. Fisher's separation theorem (Fisher, 1933) implies that it is better to diversify through capital markets than through a combination of enterprises. Therefore, the model includes different insurance and credit activities. In contrast to the situation in countries where market-based crop insurance programmes are already established since long and abundant data is available for analysis (compare the studies of Babcock et al., 2004, Bourgeon and Chambers, 2003, Miranda, 1991, Schnitkey et al., 2003), this application requires the pre-formulation and testing of insurance and hedging products before they can be introduced to the risk programming model. The formulation and testing of financial risk management products was carried out in a preceding paper (Bokusheva et al., 2005). Several selected products were calibrated for the location of the considered enterprises and included in the model. Premium costs and indemnities were estimated based on historical yield and weather data for different coverage levels. Table 4 gives an overview on selected insurance products.

The estimations are restricted to the areas with main cultures. Special crops like potatoes, fruits and vegetables are not considered for the programming model for three reasons: First, their share of total area is relatively small. Second, they are only partially marketed and serve,

[4] Ideally, a comprehensive set of states of nature is a mutually exclusive and exhaustive set of possible descriptions of the state of the world (Chambers and Quiggin, 2000). For our purposes, the states of nature are defined by weather conditions. In a next step probabilities are attributed to all states.

to a large extent, as the basic food supply of farm labourers. Third, it is not possible to derive statistically firm distribution functions from yearly changing special cultures.

After a sharp decline during the 90ies, livestock production regains importance in Kazakhstan. It is an income-stabilizing activity for the study farm in Akmolinskaya oblast and was therefore included in the portfolio.

3 Results and Discussion

Results of correlation tests are depicted in tables 5 and 6 and show no clear diversification tendency between crops. Yield correlations range between –0.218 for wheat and perennial ley on the oblast level in East Kazakhstan and 0.792 for wheat and perennial ley on the rayon level also in East Kazakhstan. Negative correlations show a potential to hedge the yield by crop choice assuming comparable gross margins per ha. In reality this accounts only for major cash crops that can be grown on a large scale, such as wheat and sunflowers. Perennial ley was analysed in order to show the yield hedging potential for a fodder crop. It may be assumed that grain crops such as wheat and barley show similar yield tendencies to perennial ley due to their shared botanical origin. As results for East Kazakhstan depict, the correlation between wheat and ley is higher compared to sunflowers and ley, but the values show no clear tendency. On the oblast level the values are even negative. For Akmolinskaya oblast, we tested only for wheat and barley correlations, which are surprisingly low compared to other crops in other regions. Only on the level of the model farm, the yield correlation has the assumed size.

The results of the risk programming model show that decisions on a certain combination of risk management instruments depend on farm specific aspects. While for the farm in East Kazakhstan (EK) an extensive technology (see table 3, low intensity) combined with a farm-yield insurance seems to be most suitable, the decision-maker of the model farm in

Akmolinskaya oblast (AK) would apply the most input-intensive technology in combination with a rainfall-based insurance product with a coverage level of 100 per cent.

Figures 3 and 4 depict incomes by states of nature, total expected incomes, and certainty equivalents for the two analysed farms. Scenario 1 offers the full choice of technologies and insurance products to the decision-maker, scenario 2 restricts that choice to the two technologies that have not been chosen in the first scenario and scenario 3 restricts that choice even further to the less favourable technology. The scenarios marked with "C" allow credit access. R is the reference scenario including full choice of technologies, but no access to insurance products. In the case of the AK farm, the expert formulated five different states of nature, for the EK farm only three states were formulated.

The introduction of all formulated technologies and selected insurance products is able to stabilise income significantly. Compared to a scenario where the preferred technology is not available (scenarios 2, 2C, 3C), per ha income can be increased by 6 per cent for the AK and 25 per cent for the EK farm, respectively. Technological restrictions can be caused by limited access to knowledge, adequate machinery and irrigation. Restricting the access to credit has no effect in the case of the grain producer in Akmola because this farm is endowed with a large buffer of own capital. The situation is different for the EK enterprise: A restricted credit access limits immediately the scope of production and rental of land becomes infeasible. The expected income decreases by about 8 per cent.

Livestock production was included in the programming model for the case farm in Akmola. It is of growing importance for the Kazakhstani agricultural sector and might support income stabilization. The World Bank stresses the importance of reviving the livestock sector in Kazakhstan and recommends to make use of comparative advantages through capitalization of the vast, but under-exploited rangeland resources mainly for extensive cattle and sheep raising in the South and in the North (World Bank, 2004). Livestock activities are not included in the optimal solution for the case farm in Akmola, because of its still relatively low profitability. Whereas livestock in the early transition phase was produced for self-provision, the share of livestock production and its productivity were steadily increasing during recent years. For the future strategy of the enterprise, production and processing of livestock products plays an important role.

The actual production policy of many Kazakhstani farms, namely a low rate of investments and savings, is myopic. Disinvestments in soil fertility as a result of monocultures and the non-application of fertilisers negatively influence the long-term yield potential. The current situation has its roots in a number of reasons, including lack of capital, effective machinery and qualified workforce. Positive development of an enterprise's financial situation might solve a part of the problems connected to it, such as "monocultures without alternative". According to the actual MoA statements, the wheat area is planned to be reduced significantly to make room for other cultures, like rapeseed, soybeans, barley, hard wheat, and rye (Agency Agrofakt, 2005). This could have a positive effect on producer prices and increase political pressure on farmers to diversify their crop portfolio.

4 SUMMARY OF FINDINGS AND CONCLUSIONS

We analysed the potential of different risk management technologies to increase and stabilise income. Results from correlation analysis indicate that income stabilising possibilities by means of production portfolio selection under the prevailing technological conditions as well as geographical diversification are limited. Model results indicate that adequate production technology is the precondition for insuring the base risk which cannot be insured by the market. Additionally, access to credit and to a range of insurance products significantly reduces risk and thereby increases decision-makers' utility. For farm managers and their employees in Kazakhstan, who decide about risk management options, these results provide a base of information about potential production technologies and crop insurance products that can help to stabilise their income.

Policy-makers and insurance companies have to consider regional differences in natural conditions, when designing and implementing crop insurance products.

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APPENDIX

Tables

Table 1 Characterisation of case farms

	Akmolinskaya	East Kazakhstan
legal form	Ltd.	Ltd.
year of foundation	1998	1996
actual size (crop area in ha)	34272	3100
irrigated area	-	-
number of employees (mean 2000-2003)	100	63
own capital (mean 2000-2003) in thous. KZT	349397	28795
income from		
crop production	85	100
livestock production	12	
processing	3	
specialisation	wheat, barley	wheat, sunflowers
average yield power	35	62
average wheat yield (1999-2003)	13.9	19.6
coefficient of variation (1999-2003)	0.117	0.203
future investment intentions	processing, air operations	-

Table 2 Characterisation of considered wheat production technologies in Akmolinskaya Oblast

Characteristics	Technology I	Technology II	Technology III
Total variable costs (KZT/ha)*	15623	10083	7114
N input (kg/ha)	200	-	-
P input (kg/ha)	150	100	-
Costs of plant protection (KZT/ha)	1440	480	-
Labour input (man-hours/ha)	4.95	4.37	3.50
Fuel input (kg/ha)	119	107	88

Snow collection	Yes (by mustard cultivation in fall)	Yes (2* mechanic. snow piling)	No
Expected. wheat yield (t/ha), (strong drought, p**=.04)	0.63	0.4	0.4
Expected wheat yield (t/ha), (average drought, p=.3)	1.08	0.6	0.5
Expected wheat yield (t/ha), (weak drought, p=.09)	1.19	0.9	0.7
Expected wheat yield (t/ha), (favourable weather conditions, p=.52)	1.45	1.01	0.85
Expected wheat yield (t/ha), (very fav. weather conditions, p=.04)	2.1	1.35	1.15

• Future variable costs might increase in Kazakhstan: Leading politicians plan to pay less subsidies for inputs, instead increase credit volume and reduce taxes for investments in processing and high-value added products (Agra-Europe, 2005); ** p=probability*

Table 3 Description of production technologies for wheat and sunflowers in East Kazakhstan

Crop	Wheat						Sunflowers					
Intensity	High		Medium		Low		High		Medium		Low	
	variable costs	fuel input	variable costs	fuel input	variable costs	fuel input	variable costs	fuel input	variable costs	fuel input	variable costs	fuel input
Operation	KZT/ha	kg/ha	KZT/ha	kg/ha	KZT/ha	kg/ha	KZT/ha	kg/ha	KZT/ha	kg/ha	KZT/ha	kg/ha
Skim poughing	1000	20	1000	20	1000	20	1000	20	1000	20	1000	20
Ploughing	2000	25	2000	25	2000	25	2000	25	2000	25	2000	25
Harrowing	500	15	500	15	500	15	500	15	500	15	500	15
Seedbed preparation	1000	20	0	0	0	0	1000	20	0	0	0	0
Levelling	800	20	0	0	0	0	800	20	0	0	0	0
Seedbed preparation	1000	20	1000	20	0	0	1000	20	1000	20	0	0
Harrowing	500	15	500	15	500	15	500	15	500	15	500	15
Seedbed preparation	0	0	0	0	0	0	1000	20	1000	20	0	0
Sowing	1000	20	1000	20	1000	20	1000	20	1000	20	1000	20
Fertilising	1000	15	500	15	0	0	1000	15	500	15	0	0
Application of herbicides	1000	15	500	15	0	0	1000	15	500	15	0	0
Harvest	1500	20	1500	20	1500	20	1500	20	1500	20	1500	20
Total		205		165		115		225		185		115
Total costs	11300	6150	8500	4950	6500	3450	12300	6750	9500	5550	6500	3450

** variable costs include machinery costs (25%), salary for the agronomist (25%), and salary for the tractor driver (50%)*

Table 4 Overview of selected insurance products

Insurance Product	Description
FYI	Farm yield insurance
AYFNat	Future based on national yields
AYINat	Area yield insurance based on national yields
AYIObl	Area yield insurance based on oblast yields
AYIRay	Area yield insurance based on rayon yields
WBIIRain	Insurance based on a rainfall index (adjusted to farm yields)
WBIIPed	Insurance based on a drought index developed by Ped[5] (adjusted to farm yields)
WBIISel	Insurance based on a drought index developed by Selyaninov[6] (adjusted to farm yields)

[5] Quoted in Shamen (1997)
[6] Quoted in Shamen (1997)

Table 5 Yield correlations of main crops on different levels (East Kazakhstan)

East Kazakhstan (1980-1992)	Wheat	Sunflowers	Perennial ley
Wheat	1	0.571	-0.051
Sunflowers		1	-0.218
Perennial ley			1
Glubokoe (1981-2002)			
Wheat	1	0.651	0.792
Sunflowers		1	0.445
Perennial ley			1
Case farm (1981-2002)			
Wheat	1	0.161	0.332
Sunflowers		1	0.109
Perennial ley			1

Table 6 Yield correlations of main crops on different levels (Akmolinskaya oblast)

Akmolinskaya (1980-2002)	Wheat	Barley
Wheat	1	0.234
Barley		1
Tselinogradski (1980-2002)		
Wheat	1	0.286
Barley		1
case farm (1980-2002)		
Wheat	1	0.784
Barley		1

Figures

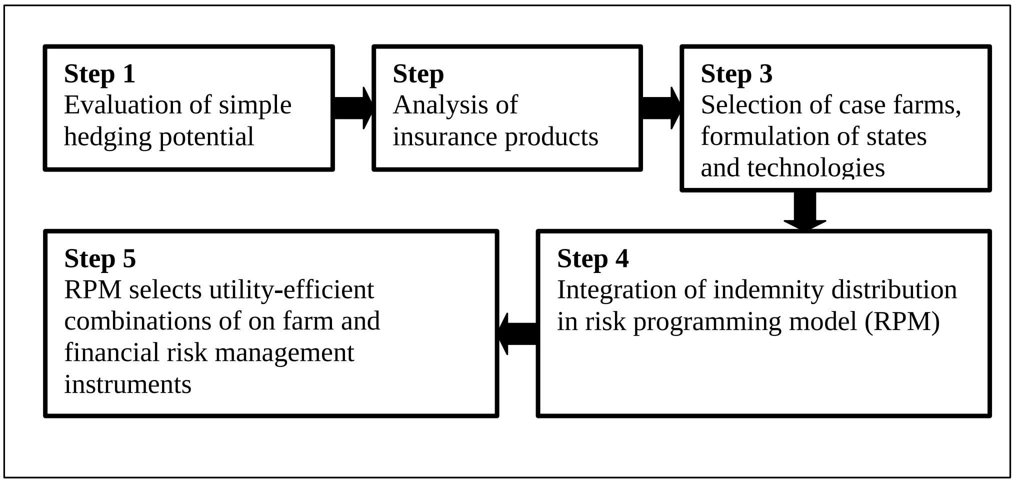

Figure 1 Steps in model building

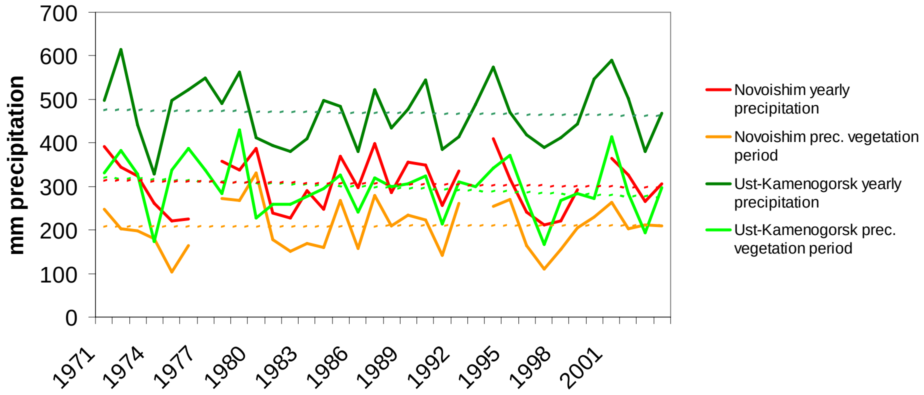

Figure 2 Climatic conditions in Central and East Kazakhstan

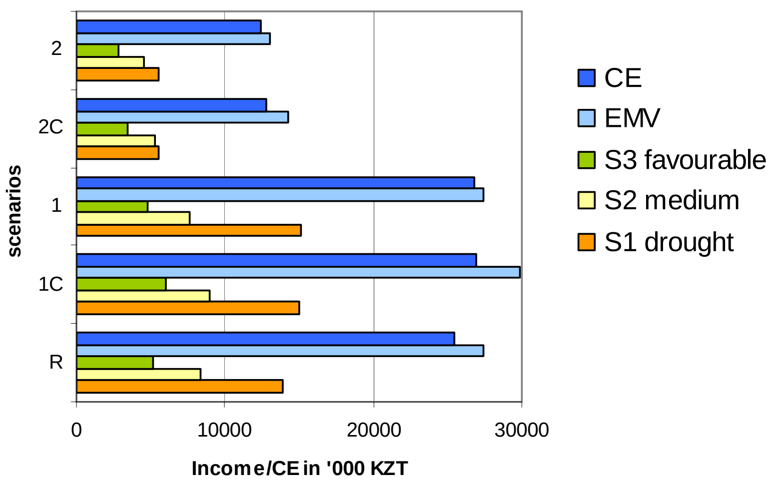

Figure 3 Income by states of nature, expected monetary value (EMV) and certainty equivalent (CE) for different scenarios – case farm in East Kazakhstan

(p(s1) = 0.56; p(s2) = 0.30; p(s3) = 0.13)

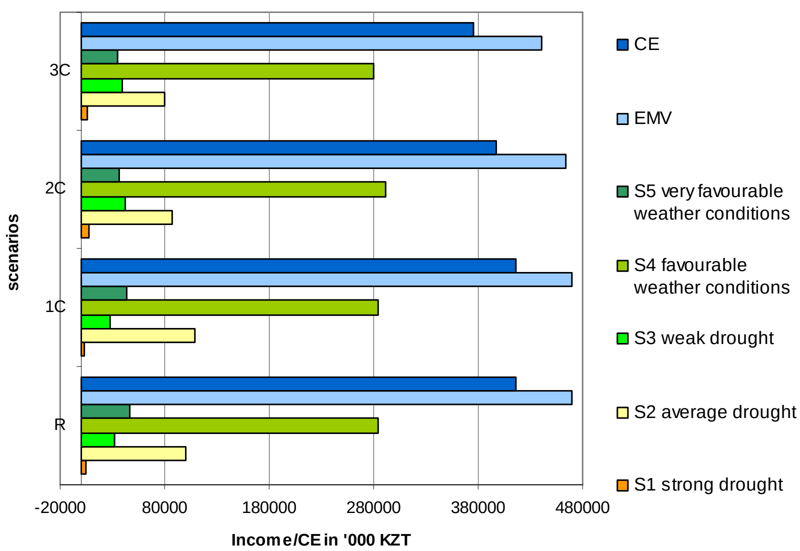

Figure 4 Income by states of nature, expected monetary value (EMV) and certainty equivalent (CE) for different scenarios – case farm in Akmola

(p(s1) = 0.04; p(s2) = 0.30; p(s3) = 0.09; p(s4) = 0.52; p(s5) = 0.04)