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CLIMATE AND INSTITUTIONAL CHANGE VERSUS EXPECTED ECONOMIC PERFORMANCE OF AGRICULTURAL HOLDINGS*

Abstract

Climate change, liberalisation of international trade in agricultural products and changes in the system of farms' support result in the increasing importance of the risk problem in European and Polish agriculture. It can be expected that a change in market and production conditions will result in significant increase in income volatility. The scale of change will depend on the financial support directed to agricultural sector and farmers' reactions.

The study reveals that in the case of Poland the most likely scenario results in rather moderate deterioration in farms' financial results measured under risk. Extreme deterioration can be observed in the liberal scenario under assumption of financial support elimination.

Introduction

Agriculture is exposed to the impact of various risk factors. In addition to the types of risk common for most of economic activities (like, for example, price relationships or loss of contractors), farmers have to tackle factors typical of agricultural activity and resulting from the biological character of production processes. The phenomena most often named in relation to agricultural production include: droughts, hailstorms, frost, floods, etc. (Langeveld et al. 2003), and also epidemics (such as BSE, swine flu) and diseases linked to livestock rearing and farming (Hurine et al. 2003). The burden of many risk factors in agriculture translates into high variation of both production and economic performance and, consequently, into uncertainty of agricultural producers as to whether or not they will achieve the expected income effects (Robinson and Barry 1987, Hardaker 2000).

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The problem is not new, but in the last years it has attracted increasingly more attention, which is manifested in the greater variation of (both production and economic) performance in agriculture (Vrolijk et al. 2009, European Commission 2008, European Commission 2011). According to the European Commission's calculations, 1/4 of farms from the EU-15 countries suffered income loss of more than 30% in the period between 1998 and 2003. Other documents (European Commission 2011), show that ca. 20% of farmers in Europe incurs losses resulting from a drop in income at the level above 30% of the average values form former years.

The reasons for the growing variation in yields and incomes in agriculture can be grouped into three basic categories. The first group concerns production aspect and is linked to climate change that has been intensifying for several decades (Alcamo et al. 2007, Olesen J.E. et al. 2011, Kundzewicz and Kozyra 2011). Slow, but progressing liberalisation in the international trade in agricultural products is named as the second of the key reasons for declining stability in agriculture (Bureau et al. 2005, CBD 2005, Wróbel 2012). The third group pertains to the changes in the Common Agricultural Policy, which result, e.g., from negotiations under the WTO on trade liberalisation and constitute an attempt at tackling the challenges linked to climate change (Matthews 2010, Majewski et al. 2008, Asseldonk et al. 2008, Tangermann 2011). It should be emphasised that destabilising effect of the risk factors on the side of supply (weather and climate) is strengthened in agriculture by low elasticity of demand (Akcaoz 2009 as in Meuwissen 2001), which, in turn, may cause disproportionately strong responses of the prices of agricultural products to changes in supply (this provides an opportunity for above average profits but also increases the probability of serious losses). Additionally, risk capital transactions (Chądzyński 2011, Schutter 2010), exclusion of some part of lands from food production and their allocation to energy crops (Ajanovic 2011, FAO 2013, UN 2009, Wahl 2009, Gradziuk 2008) and growing demand for food in developing countries, such as China and India (Mierzwa 2007), are considered as increasingly important in destabilising the situation in respective agricultural markets.

Given that the observed processes will probably intensify in the future, it can be expected that conditions for agricultural production will clearly change. According to Kundzewicz and Kozyra (2011), as regards future climatic conditions "our knowledge is limited and fraught with considerable uncertainty", but although projections are "quantitatively uncertain, in qualitative terms changes are predictable". The estimation of the future shape of agricultural policy and conditions in agricultural markets seems quite difficult. The changes taking place will rather have an evolutionary character, but it cannot be ruled out that some conditions in the agricultural surroundings will alter radically in the perspective of several or several dozen years. Agricultural policy, for which modifications in the form of an institutional shock are possible, appears to be an area especially prone to such radical change. In the face of imprecise character of different projections, an attempt at estimating the impact of change in conditions in the area of agriculture on the running of farms may be carried out only with the use of scenario analysis that reflects diverse possibilities pertaining to the future conditions of operation.

The paper primarily aimed at assessment of the level of changes and variation of expected economic results of agricultural holdings estimated taking into account the stance of farmers against risk, and it tried to define their likely responses to the changes in external conditions. The implementation of thus formulated objective required detailed analyses on the possible changes covered by the scenario considerations (in the context of 3 areas, i.e. climate, trade liberalisation – price volatility, Common Agricultural Policy).

Impact of climate change on agriculture

Even though the issue of climate change is still highly controversial in the public debate (especially in the context of implementing mechanisms of counteracting thereof) (Philander 2000, Piątek 2010), climatologists have no doubts that climate change is a fact and that it is not neutral to agriculture (Kundzewicz, Kozyra 2011). Increasingly more common extreme weather conditions, such as droughts, floods, heat spells or heavy rains, even now cause substantial losses in yields of arable crops and soil degradation by erosion (Matyka et al. 2014) and it should be expected that in the future the processes will strengthen. In general, six basic processes, which can translate into agricultural production in different manner, can be indicated as regards the impact of climate change on agriculture (Olesen 2011). The first one, refers to the rising CO_2 concentration and its impact on the productivity of crops and the use of water resources and nutrients; the second one, concerns changes in agroclimate parameters having a direct impact on crop development and yields (temperature, precipitation, insolation); the third one, points to the changes in the frequency of atmospheric events of catastrophic consequences (heat spells, droughts, floods); the fourth one, pertains to changes in suitability of different species in a given geographical region; the fifth one, relates to changes in mechanisms of plant nutrition and incidence of diseases, weeds and pests; while the sixth one, involves the impact of climate change on the quality of soil environment (Olsen et al. 2001). The first three ones of the aforementioned mechanisms directly influence agricultural production and the latter ones – indirectly (Bański, Błażejczyk 2005). Each of the above-mentioned processes can have a different impact depending on the geographical area and type of farming.

Increasing air temperatures are considered as one of the key manifestations of climate change. Observations of climatologists indicate that in the 20th century the average annual air temperature in Poland rose by 1°C (Górski 2006). The forecasts developed under the PRUDENCE project predict that, by the end of the 21st century, the average temperature in Poland will grow by 3.5°C as compared to the 1961-1990 period (Kozyra, Górski 2008). According to Kundzewicz and Kozyra (2011), global warming at the level of 0.2°C per decade should be expected. It is assumed that temperature growth by 1°C speeds up cultivation of, e.g., maize by 2 weeks (Rosa 2013) and wheat ripening by 1 week (Górski 2006). It is projected (Deputat 1999) that temperature growth by 3-4°C will bring forward the date of spring cereals sowing by 3 weeks and the dates of harvest by even 3-4 weeks. This may eliminate barriers to cultivation of thermophilic crops (e.g. maize, soya, sunflower).

Temperature increase prolongs the growing season and extends the possibilities of cultivating crops of higher temperature requirements. Climate change does not consist only in temperature growth, though. "All elements of the interconnected systems of climate and water resources, change along with the temperature and, consequently, also many physical, biological and human (socio-economic) systems" (Kundzewicz, Kozyra 2011). Warmer climate greatly rises the risk of drought (Rosenzweig et al. 2007). Although it favours increase in precipitation intensity as well, it, at the same time, increases the risk of flood. It should be expected that further climate change will cause reduced water store in soil. The progressing climate change in the context of agriculture results in an increase in the frequency of years of negative production conditions and thus in greater yielding variation from year to year (Kundzewicz, Kozyra 2011, Kozyra and Górski 2008).

Indirect effects of climate change include, for instance, changes in the range and number of pests and diseases (warm conditions favour greater number of pest generations), greater stress of thermophilic pests, changes in soil temperature rising the activity of soil phytopathogens, possibilities of modification of plant tolerance to herbicide resulting from ozone concentration in the atmosphere (Lipa 2008), increased scale of winter survival by weeds and pests due to warmer winters (Matyka et al. 2014). Higher temperature and increased carbon dioxide concentration in the atmosphere may rise the intensity of photosynthesis, thereby making the tissues of some plants softer and more susceptible to infections, and of others more lignified (Wong 1999 as in Lipa 2008). Because of temperature growth and shift in the range of cultivation of certain arable crops (e.g. maize), the pests move as well, e.g. cornmoth (Lisowicz 2003 as in Kundzewicz, Kozyra 2011). It should be emphasised that, in addition to the negative effects, the observed climate change can result also in some positive processes. For instance, higher temperatures reduce the plant ripening time making it possible to grow more catch crops. As mentioned before, climate change increases the possibilities of cultivation of some plants thereby extending the scale of possible diversification of crop structure (but the risk of low yields grows at the same time).

Taking into account the comprehensive nature of the issue, it is difficult to present all the potential consequences of climate change for agricultural production, especially those of intermediate character (for instance, because of still insufficient knowledge on some effects of intermediate nature (Kundzewicz, Kozyra 2011)). Table 1 contains the basic consequences of climate change for cultivation of the major arable crops in Poland.

Table 1

The expected impact of climate change on the major crops in Poland

Arable crop	What is the impact of climate change? – positive	What is the impact of climate change? – negative
Winter cereals	Projected warmer and longer autumn allows starting sowing later than before, mild winters favour better overwintering.	More frequent droughts in the autumn period – poor conditions for early development stages.
Spring cereals	Earlier warmer springs favour improvement of sowing conditions and early growth stage.	Frequent draughts in the intensive plant growth period reduce yields. High temperatures shorten the biomass accumulation period – lower yields.
Potatoes	Early and warmer spring – better planting conditions and better conditions at the early development stages.	High temperature in the growing season and droughts – lower yields.
Beets	Early and warmer spring – better sowing conditions and better conditions at the early development stages. Longer and warmer autumn – better conditions in the harvest – longer season.	More frequent droughts, yield fluctuations over the years.
Maize	Better thermal conditions increased the opportunities for cultivation of thermophilic plants in central and even north-western regions of the country. Temperature growth by another degree will eliminate barriers to cultivation of medium-late maize (FAO 270) in Poland.	More frequent droughts – drop in yields in dry years.

Source: Nieróbca A., 2009, Mizak K. et al. 2012.

As regards climate change, it should be highlighted that, although its direction and impact on agriculture can be approximated on the global scale, its range and even character can differ substantially depending on geographical location. Figure 1 presents the likely impact of climate change on agriculture in Europe. From the above it follows that Poland is in the zone in which the main changes are linked to the projected increase in winter rainfall and the possibility of more frequent floods related thereto, and to a drop in summer rainfall that will translate into water stress and resultant drought risk and, finally, greater production fluctuations. At the same time, the phenomenon of water erosion will strengthen but longer growing season may favour higher yields and increase in the spatial range of some crops. The negative consequences for agriculture will be the strongest in southern Europe. As a result of climate change, agricultural production conditions in northern Europe may improve rather clearly. In this context, Poland is in the zone in which the impact of climate change on agriculture may be estimated as fairly moderate.

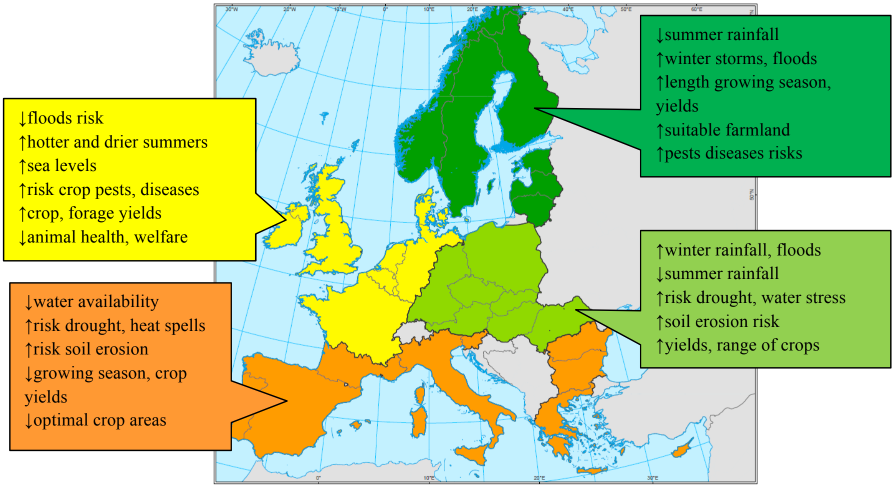

Fig. 1. The likely impact of climate change on agriculture in different EU regions
Source: DG Agri 2007.

Institutional and market changes

Because of inelastic demand for agricultural products, disruptions in the global supply, which result from yield variation, translate into disproportionately greater price volatility in agricultural markets. Analyses, conducted with the use of AGLINK-COSIMO model, show that yield variation explains more than half of price volatility (OECD 2011). This effect is strengthened, as mentioned before, by e.g. speculative transactions or the growing demand for food in developing countries, and by exclusion of some part of agricultural land and its allocation to cultivation of energy crops. In the several dozen years of applying the Common Agricultural Policy, the European Union markets were strongly protected by price stabilisation mechanisms (Wilkin 2006). This is reflected in a comparison of the price volatility of agricultural products in the EU countries with the global prices. The data included in Table 2 show that, for most of products, price volatility in the global markets – even in 1997-2003 – was clearly higher than in the EU countries. In 2004-2010, the gap in the level of coefficient of variation for many categories of products (especially cereals) visibly narrowed. According to Matthews (2010), the price volatility increases along with implementation of subsequent CAP reforms.

The observed increase in price volatility in the EU markets was a derivative of restrictions in the application of direct market intervention instruments which, in turn, stemmed from the pressure exercised by third-country trade partners on the EU decision makers (Kaczurba 2004). Numerous analyses (Michałek and Wilkin (2008), Skrzypczyńska (2011), Wróbel (2012)) show that, for a long time, the EU (but also e.g. the USA) quite efficiently limited the import of agricultural products from third countries, which resulted from disruptions in the global markets and became one of the key axes of the conflict during subsequent negotiation rounds at the forum of the World Trade Organization (former GATT). In the context, the Agreement on Agriculture, concluded during the GATT Uruguay Round (the round started in 1987 and continued for 87 months), was especially significant as it forced the Community countries to introduce substantial changes to the Common Agricultural Policy (Wróbel 2012). The Doha Round, which has started in 2001 and continues until today, provided a stimuli for more changes in the Common Agricultural Policy. Despite the lack of final agreements, the Round exerts pressure on further liberalisation of trade in agricultural products. Apart from external emphasis, the issue of growing social dissatisfaction of the EU countries, which increasingly more often insist on limiting the level of support, is more and more important as regards the level and form of subsidies to agriculture (and stability of the markets and incomes) (Eurobarometr 2011).

Table 2

Comparison of the coefficient of variation for prices of selected agricultural products in the global and European Union markets

Product	The global prices		The EU prices	
	period			
	1997-2003	2004-2010	1997-2003	2004-2010
	coefficient of variation (%) for a given period			
Barley	15.42	31.05	6.39	26.26
Wheat	17.32	33.23	5.82	27.54
Maize	11.96	30.17	5.64	23.23
Butter	16.93	35.72	3.47	12.84
Milk powder	17.66	33.03	8.35	18.31
Poultry	5.57	8.42	6.15	9.28
Beef	9.77	13	4.07	5.4

Source: Tothova M. 2011 on the basis of data from the DG Agriculture and Rural Development and the World Bank.

Future changes in the agricultural policy may directly or indirectly influence the level of risk in agriculture. From historical perspective, direct income referred to introduction or withdrawal of different instruments that affected the price level and volatility (e.g. intervention prices). Today, direct payments are the key tools for stabilising the economic situation in agriculture. Although they are not responsible for price formation, they increase income stability by providing farmers with a specified value of support which is guaranteed over a predetermined time horizon (Majewski et al. 2008, Cafiero et al. 2007). Given the fact that agricultural policy changes due to modifications in the social, political and economic conditions, it may be stated that instead of a stabilising factor it starts to become a risk factor itself (its shape is unpredictable in subsequent budgetary perspectives). Authors, such as Anton and Giner (2005), point to the destabilising role of the Common Agricultural Policy reforms. However, it needs to be highlighted that, from the historical perspective, an increase in price volatility, caused by market liberalisation, was never translated into a growth in the income fluctuations (Cafiero et al. 2007). Limiting the subsidies to prices as a result of McSharry's reform increased their volatility but, simultaneously, direct payments improved the stability of income in agriculture (Commission 2008).

Bearing in mind the lessons learned over the last several dozen years, both concerning the changes in the shape of the EU agricultural policy and partially determining these reforms of liberalisation processes in trade, it may be assumed that price volatility in the next years will undergo gradual intensification. Changes in the scope of agricultural income are more unpredictable because, under the current shape of support, its stability depends largely on the political factor.

Data sources

The research had a model character. Twelve models of agricultural holdings differentiated by type of farming and economic size were elaborated to implement the research objective. Farms participating in the FADN system in selected types of farming were used as prototypes for the models. The models were build up on the basis of average values of a given type (group). The analyses covered the following groups of farms (separated in line with the nTF14 FADN classification)[1]:

- crop holdings – including holdings specialist in field crops (nTF1x)[2], horticultural crops (nTF2x), permanent crops (nTF3x) and mixed crops (nTF6x),
- cattle holdings – including holdings specialist in grazing livestock (nTF4x) and mixed holdings in the subtype "mixed livestock" (nTF7x)[3],
- pig holdings – including units specialist in granivores (mainly pigs) (nTF5x).

Each group was divided into small farms (Standard Output (SO) at EUR 4-25 thousand), medium-sized (SO at EUR 25-100 thousand) and large farms (SO > EUR 100 thousand).

Due to the multi-sided character of the analysed phenomenon the analysis required the use of a lot of empirical data and many assumptions. The assumptions, in most of the cases, were taken from long-term forecasts and projections published by the national and international institutions analysing the situation in the

[1] Detailed information on the typology of agricultural holdings applied by the FADN and principles of their denotation contained in: Analiza skutków zmian we Wspólnotowej Typologii Gospodarstw Rolnych. Wyd. IERiGŻ-PIB, 2010.

[2] "x" – means the second digit in the codes of types of farms according to the nTF14 typology, e.g. nTF2x stands for all types of farms specialist in horticulture, i.e. nTF21 (horticultural crops under protective cover), nTF22 (outdoor horticultural crops), nTF23 (other horticultural crops), etc.

[3] Inclusion into the group of "cattle" the farms of the type "mixed livestock" resulted from the fact that in technological sense these are closer to holdings specialist in cattle rearing than to any other type of farming.

agricultural markets and in agricultural surroundings. Extrapolation of the trend function was used in some cases. If no forecasts or data allowing to precisely estimate the value of the parameters were available, assumptions were based on expert's knowledge. Detailed information on the sources of assumptions was presented in the detailed description of the scenarios.

Data from the FADN data base (production structure, level of costs), the Central Statistical Office [*Główny Urząd Statystyczny*, GUS] (long time series to estimate variation and value of the expected yields and prices), calculations of the agricultural advisory centres (to estimate the surpluses for individual types of farming), and a number of forecasts concerning the probable changes in the agricultural surroundings in the future were used to build up the farm models. The paper also uses information on the coefficient of risk aversion, which – for the groups of farms being the prototypes for the models – was estimated in a different paper (Sulewski 2014), and information on the possible responses of farmers taken from field studies conducted on a representative sample of 600 agricultural holdings (also described in detail in the aforementioned paper).

Models

The models used in the paper were built up with the application of the "mean – variance" approach derived from the H. Markovitz's Portfolio Theory (1952) (Mean-Variance Portfolio Theory). The approach identifies the mean with the expected value of a defined parameter, and the variance is treated as the risk measure. The key task was maximisation of the value of certainty equivalent (CE) at a defined level of the Arrow-Pratt's coefficient of risk aversion (Pratt 1964, Arrow 1965) described as follows (Hardaker 2000; Hazel and Norton 1986):

$$max\ CE = E(i) - \frac{\theta}{2E(i)} V(i)$$

where:
$E(i)$ – the value of expected agricultural income,
$V(i)$ – income volatility,
θ – coefficient of (absolute) risk aversion.

The certainty equivalent reflects a given value lower than the expected value (for winning) for which the decision-maker would be willing to resign from participation in a risky game. The value of income that is possible to be generated (profit) can be an equivalent of winning in terms of economic activity (cf. Damodaran 2009).

And the expected value of income was calculated as follows:

$$E(i) = \sum_{i=1}^{n} E(GM_i)x_i - FK$$

where:

$\sum_{i=1}^{n} E(GM_i)\mathrm{x}_i$ – stands for the sum of the value of the expected gross margins from ith activities multiplied by the cultivation area (or number of animals) of each of them,

x_i – expressed in ha (or structural units has the character of a decision variable and undergoes optimisation in the nonlinear programming problem),

FK – stands for fixed costs.

The gross margin values were calculated according to the formula:

$$E(GM) = E(S) + VC$$

where:

E(S) – stands for the value of revenues from the i^{th} crop (calculated as an quotient of the price and value of unit production),

VC – variable costs.

Because of the assumption on the deterministic nature of variable and fixed costs the variance in agricultural income reflected only the yield (efficiency) variation and price volatility of individual products and was calculated in line with the following formula:

$$\mathrm{V(i)} = \sum_{i=1}^{n} V(R_i)\mathrm{x}_i^2 + 2\sum_{i=1}^{n} \sum_{j=i+1}^{n} x_i x_j \operatorname{cov}_{ij};$$

where:

$V(R_i)$ – means variance of revenues from i^{th} activity,

cov_{ij} – means covariance of revenues between individual pairs of activities, which reflects the correlation between both yields and prices.

To extend the scope of information concerning the probable formation of a phenomenon in the future, input values (i.e. value and variation of yields and prices, and unit efficiencies) were simulated with the use of Monte Carlo method. The simulation applied the historical values of simulated parameters derived from empirical observations as input parameters (they formed the grounds for determining such parameters of distribution as mean and standard deviation). This allowed to obtain 10 thousand replications for variables covered by the simulation and 10 thousand observations of financial results for each scenario and model farm. To simplify the analysis, the simulations were carried out only upon assumption of normal distribution of individual parameters, at the same time, restricting the scope of their variation to plus/minus three standard deviations (eliminating the risk of drawing out negative input parameters).

Table 3

Input structure of crops and selected parameters of characteristics of model farms

	SPECIFICATION	Economic size by standard output											
		EUR 4-25 thousand				EUR 25-100 thousand				> EUR 100 thousand			
		Cattle	Mixed	Crop	Pigs	Cattle	Mixed	Crop	Pigs	Cattle	Mixed	Crop	Pigs
Crop structure (% in sowing)	Wheat	6.4	9.3	27.9	5.7	7.6	14.5	31.1	13.0	0.0	23.2	28.7	11.3
	Cereal blends	26.8	21.7	5.8	55.7	21.4	19.0	5.0	20.4	6.2	6.9	6.0	28.4
	Other cereals	32.9	33.2	41.4	34.0	23.9	39.2	36.4	63.0	36.8	35.3	35.1	53.3
	Rape and industrial crops	0.2	1.7	14.0	0.0	0.9	6.0	18.2	1.0	0.0	18.8	18.1	1.3
	Protein crops	2.1	3.7	3.7	0.7	1.4	4.8	3.5	0.3	0.0	4.1	3.4	5.0
	Beets	0.0	0.6	2.3	0.0	0.4	3.3	4.7	0.4	0.0	5.5	2.7	0.6
	Potatoes	2.3	2.6	3.3	3.9	0.7	2.5	0.8	0.8	0.0	0.8	1.6	0.0
	Fodder crops (fodder roots + silage maize)	17.1	21.9	0.1	0.0	23.4	6.9	0.1	0.5	37.3	3.9	3.3	0.0
	Other	12.2	5.2	1.4	0.0	20.4	3.9	0.2	0.6	19.8	1.4	1.1	0.2
Other parameters	UAA (ha)	11.7	15.2	22.1	9.1	33.9	39.0	94.8	25.5	116.9	115.0	305.2	64.6
	Arable land (ha)	7.5	10.5	20.5	8.8	22.7	34.2	92.8	24.9	73.4	109.9	301.6	63.6
	Labour force (AWU)	2.3	2.4	2.2	2.5	2.6	2.6	2.4	2.3	2.9	2.5	2.3	2.8
	Total cattle (livestock unit)	11.7	4.1	0.5	0.5	37.6	16.1	1.1	0.7	155.7	19.1	1.2	0.0
	Pigs (livestock units)	0.6	4.0	1.0	13.0	0.6	20.4	2.9	57.0	0.0	105.7	17.6	156.6

Source: own research.

Table 4

Coefficient of risk aversion for model farms broken down by production directions and economic strength

Economic size	Type of farming			
	Crop	Cattle	Pigs	Mixed
SO: EUR 4-25 thousand	2.59	2.57	2.43	2.76
SO: EUR 25-100 thousand	2.42	2.32	2.32	2.59
> SO: EUR 100 thousand	1.69	2.30	2.30	2.09

Source: Sulewski P. 2014.

Table 3 presents the basic parameters regarding the production characteristics of model agricultural holdings. But then, Table 4 includes information on the average level of the Arrow-Pratt's coefficient of relative risk aversion identified for farms being the prototypes of the prepared models, according to the procedure presented in another paper. As regards the presented coefficient of risk aversion, it should be emphasised that according to Anderson and Dillon (1992), its value equal to 1 suggests grounds for slight aversion, value 2 – fairly average, value 3 – rather strong aversion, while value 4 – extremely strong risk aversion. In the case of model farms, it should be noted that the average aversion was greater for smaller farms and lower for larger farms. From the point of view of the direction of production, slightly lower aversion was observed for pig and crop holdings, and higher for cattle and mixed holdings.

Scenarios

Given that the budgetary perspective, started in 2014, sets the framework for agricultural policy by 2020, it was decided to conduct model analyses going beyond that period – 2023 was taken as the point of reference. But, taking into account the character of phenomena considered in the analysis that spring, *inter alia*, from institutional factors (shape of the CAP), the date should be treated conventionally – as a point in the future for which, at present, it is difficult to unambiguously "outline" a dominating variant (hence considerations thereon are in a form of scenarios). The built up scenarios are based on the previously discussed trends observed under three dimensions recognised as key sources of risk growth in agriculture (climate, market and policy). Each of the considered scenarios refers to the probable changes concerning each of these dimensions. Although changes in each of the dimensions can take on different range, it was decided that only 4 synthetic scenarios will be presented, which, according to the authors, may reflect a wide scope of the potential impact of various conditions on the situation of agricultural holdings of diverse types of farming, i.e.:

– baseline scenario,
– probable scenario,
– optimisation scenario,
– liberal scenario.

The baseline scenario reflects the situation of 2012, but considering the changes resulting from the new CAP regulations linked to the so-called greening (Regulation (EU) no. 1307/2013 of the European Parliament and of the Council) that will be applicable until 2020. When building up the scenarios it was assumed that if the model holding (based on means for the selected types) fails to meet the requirements following from the CAP "greening", under restricting conditions a parameter was introduced which enforced such adjustment by increasing the EFA[4] to the minimum required level. Bearing in mind the aim of the paper, differences resulting from introduction of the "greening" requirement will not be presented – the principles of the regulation were implemented into the legislation and, at present, they are not a factor of institutional risk. Detailed analyses concerning the impact of the tool on the Polish farms were presented, for instance, in the following papers: Czekaj et al. (2014), Wąs et al. (2013). The baseline scenario does not assume any changes in the amount or variation of the yields, thus it can be taken as a reference point for other scenarios considering the necessary adjustments following from the shape of agricultural policy binding as of 2014.

The probable scenario, reflecting the expected changes, is the underlying scenario. The changes in the level of yields under the scenario were taken as the mean from three scenarios developed by the experts from the Institute of Soil Science and Plant Cultivation in Puławy under the project "Klimat" (www.imgw.pl)[5] (Figure 2). The developed projections refer both to the positive effects following from the expected increase in yielding, owning to better organisation and intensification of production, and also to the negative effects due to unfavourable impact of climate change. It should be emphasised that an increase in the amount of expected yields is assumed for all the crops, except for spring wheat. In case of arable crops, for which there were no scenarios available under the "Klimat" project (owing to no data), the mean for a crop of similar cultivation practice was taken as an index of growth for the probable scenario. Given that the assumed changes in yielding are the resultant of, e.g., production intensification, it was predicted that the inputs (as a consequence of costs) on mineral fertilisers and plant protection products will grow, against the actual data, by 10%[6] – regardless of changes following from the forecast as regards conditions

[4] EFA – Ecological Focus Area. Only farms of more than 15 ha of arable lands will be covered by the obligation to allocate at least 5% of arable land in a holding to environmental areas.

[5] Task 1. Climate change and its impact on the natural environment in Poland and identification of their economic effects. Identification of the impact of climate change in yielding of the key arable crops in Poland *[Zmiany klimatu i ich wpływ na środowisko naturalne Polski oraz określenie ich skutków ekonomicznych. Określenie wpływu zmian klimatu na plonowanie głównych roślin uprawnych w Polsce]*. http://klimat.imgw.pl/wp-content/uploads/2013/01/1_29.pdf.

[6] It is expected that the consumption of nitrogenous fertilisers will grow by 2019 at an average growth rate of 1.2% in the EU-27 countries and much faster in the EU-12 countries. Given that it is already at a rather high level in Poland, it was assumed that its further cumulative growth in the considered perspective will be at the level of 10%. The same level was assumed for the growth in the consumption of plant protection products.

in the market of means of production. As for the coefficient of variation of yield, it was postulated that under the probable scenario its value increased by 50% against the baseline scenario. This assumption springs from the above-discussed predictions pertaining to the impact of further climate change on agriculture and from observations of changes that occurred in the field of yield fluctuations from the beginning of the 1990s. For example, the coefficient of variation, in the period from 1990 to 2007 against the 1955-1971 period, for wheat increased from 0.06 to 0.094 (i.e. by 56%), and for spring barely from 0.062 to 0.082 (Górski et al. 2008).

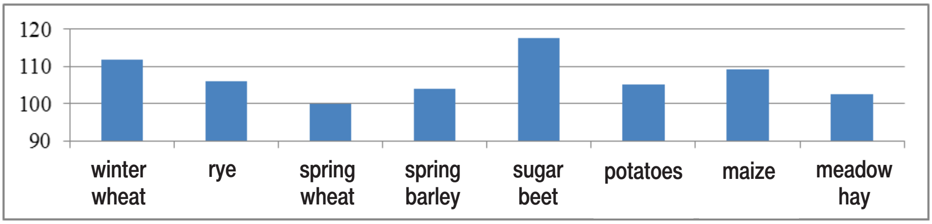

Fig. 2. The scope of change in the expected level of yield for selected arable crops
Source: "Klimat" project, www.imgw.pl.

In the case of livestock activities, it was assumed for the probable scenario that the yield of dairy cows in the considered time perspective will grow by 11.3% (estimated on the basis of extrapolation of the trend function at $R^2 = 0.97$). With regard to milk yield, it needs to be highlighted that it shows a clear upward trend and it is, on average, higher from year to year, which means that variation results not so much from fluctuations of the parameter as from its growth. However, bearing in mind the possibility of "transfer of losses" from crop to livestock activities, it was decided to burden the milk yield in the model solutions with the coefficient of variation estimated for the last 10 years. In the case of pigs, it was assumed that the productivity of sows will rise by 5%, while the growth in coefficients of variation in pig production was arbitrarily set at 7%, because of no relevant time series.

The scope of changes in product prices was determined on the basis of a projection of the European Commission (European Commission 2013) prepared for the entire EU. Taking into account the expected growth in yield variation and increasingly greater dependence of the domestic (and the EU) market on the fluctuations on the global markets, it was assumed that the coefficient of variation of prices will grow cumulatively by 10%. The forecast of changes in prices of fertilisers was adopted on the basis of the *Commodity Markets Outlook* (World Bank Group 2014). Changes in the prices of diesel oil and energy were adopted on the basis of a forecast developed by the JRC-IPTS and the European Commission, which was presented in the OECD-FAO Outlook 2013. Table 5 contains the basic parameters for the probable scenario stemming from the adopted assumptions.

Table 5

Assumptions regarding the price and cost changes for the probable scenario

Prices/costs	Coefficient of variation (baseline scenario = 100%)
Wheat[a]	0.93
Barley[a]	0.90
Maize[a]	0.88
Other cereals[a] (mean from former years)	0.90
Oilseeds[a]	0.88
Sugar beets[a]	0.89
Milk[a]	1.04
Pigmeat[a]	1.24
Beef[a]	1.08
Energy[b]	1.15
Fertilisers[c]	0.86
Plant protection products[d]	1.03
Seeds[d]	1.05
Labour[f]	1.30
Fuel[c]	1.21
Other costs[e]	1.15

[a] European Commission; [b] World Bank; [c] OECD – FAO2013; [d] assumed at 1.2; [e] own forecasts for fertilisers; [f] extrapolation of the trend function ($R^2 = 0.95$).

Scenarios alternative to the probable scenario are characterised as follows[7]:
- optimisation scenario – assumed the possibility of changes in the crop structure at +/–50% (lessening of restrictive conditions) against the probable scenario (keeping the requirements following from the regulations on greening); other parameters remain unchanged as compared to the probable scenario;
- liberal scenario – complete elimination of support to agricultural holdings, other parameters as in the probable scenario.

Results

Table 6 contains information on the expected value of agricultural income and the certainty equivalent in individual model solutions, considering the type of farming and economic size. From the presented comparison it follows that in the baseline scenario the expected value of income reaches a level many times higher for agricultural holdings having the economic size above EUR 100 thousand SO (in every type of farming) than for smaller units. The clearly smaller differences in the discussed parameter were observed between the types of farming (but it needs

[7] As comprehensive as possible coverage of the scope of potential changes was the key assumption behind building up the alternative scenarios; hence their character can be recognised as quite extreme.

to be stressed that the scope of differences in the expected value of income between the types of farming was differentiated between groups of economic size). At the same time, the value of certainty equivalents was at the level between several and several dozen percent of the expected value of income, which reveals the theoretical scope of acceptable drop in the expected value of income for farmers showing a specific level of the coefficient of risk aversion. Given the fact that the difference between the expected value and the certainty equivalent reflects the theoretical risk cost, it can be assumed that as long as the certainty equivalent reaches positive values the scope of obtained solutions can be considered as acceptable from the economic perspective (the value of the certainty equivalent below zero would mean that a farmer, showing a specific level of risk aversion, is willing to accept negative results to avoid risk and this should be considered as counterintuitive). Therefore, it can be assumed that the real decision-maker would have introduced organisational changes allowing to limit the level of risk (e.g. greater use of insurance coverage) or he would have changed his attitude towards risk in the face of changing conditions in the surrounding (the level of acceptance for risk would increase). The solutions for which negative values of the certainty equivalent were achieved can accordingly be treated as situations requiring adjustments. From the data included in Table 6 it follows that it pertains to some part of solutions for the probable scenario and almost all for the liberal scenario. The existence of probable scenario conditions would cause a clear, but in most of the cases not radical, drop in the expected value of income. In all of the types and economic size groups this parameter remained at the level above zero, although in some of the cases the certainty equivalent dropped below zero. But it can be assumed that the conditions of the probable scenario pose, in general, a threat to the functioning of farms, even though keeping income at the level of expected value will require the implementation of the necessary adjustments. The optimisation scenario can provide an illustration of such actions as in its case the results of model farms (perceived in the category of expected value) achieve a comparable or even higher value than in the baseline scenario. Bearing in mind that farmers, apart from optimisation of the production structure may also choose from a number of risk reduction strategies (Meuwissen et al. 2001, Nguyen et al. 2007), which are used in Poland to a rather insignificant degree (Śmiglak-Krajewska 2014, Sulewski 2014), it can be assumed that the existing possibilities of adaptation will allow farmers to keep the expected value of income at the level similar to the baseline level. The case for the liberal scenario is much worse, as its results may be perceived in the categories of a "shock" caused by institutional factors. In such a case, the expected value of income (and the certainty equivalents) will drop significantly below zero for most of the types of agricultural holdings. It would be the most serious for crop holdings and the least for livestock holdings (especially pig holdings) because of the lower level of dependence of income of the latter on the level of direct support (the FADN data show that holdings specialist in field crops and mixed holdings are characterised by the highest share of payments in farm income (FADN 2012)).

Table 6

The expected value of income and certainty equivalents for model holdings by the type of farming and economic size

Type of farming	Scenario	Economic size (SO in EUR thousand)					
		EUR 4-25 thousand		EUR 25-100 thousand		> EUR 100 thousand	
		Expected value (EV) of net agricultural income	Certainty equivalent (% of EV)	Expected value (EV) of net agricultural income	Certainty equivalent (% of EV)	Expected value (EV) of net agricultural income	Certainty equivalent (% of EV)
		PLN thousand					
CROP	Baseline	7.5	52.8	40.5	45.1	169.4	79.1
	Probable	5.9	6.1	31.0	17.0	99.5	31.6
	Optimisation	11.1	66.0	44.8	57.4	127.7	49.5
	Liberal	-10.0	<0	-45.0	<0	-162.1	<0
CATTLE	Baseline	14.7	72.8	42.3	60.2	106.6	61.1
	Probable	13.5	40.0	36.5	<0	104.9	37.1
	Optimisation	14.8	48.3	38.6	8.7	108.2	40.6
	Liberal	0.24	<0	5.5	<0	31.6	<0
PIGS	Baseline	8.8	13.3	57.8	58.6	149.8	61.0
	Probable	6.7	<0	44.7	30.8	130.4	49.2
	Optimisation	7.4	<0	48.9	41.3	136.1	53.9
	Liberal	-5.5	<0	29.9	<0	96.1	6.4
MIXED	Baseline	7.9	77.4	31.4	71.6	107.9	69.5
	Probable	2.8	<0	22.9	36.6	89.4	53.9
	Optimisation	4.2	<0	27.4	53.0	103.4	63.3
	Liberal	-9.5	<0	-15.5	<0	7.1	<0

Source: own research.

Table 7

The coefficients of variation in the considered scenarios by type of farming and economic size

Type of farming	Scenario	Economic size (SO in EUR thousand)		
		EUR 4-25 thousand	EUR 25-100 thousand	> EUR 100 thousand
CROP	Baseline	0.60	0.67	0.56
	Probable	0.85	0.83	0.90
	Optimisation	0.52	0.59	0.77
	Liberal	-	-	-
CATTLE	Baseline	0.46	0.56	0.69
	Probable	0.68	0.90	0.88
	Optimisation	0.63	0.85	0.85
	Liberal	-	-	-
PIGS	Baseline	0.84	0.60	0.58
	Probable	1.12	0.77	0.68
	Optimisation	1.02	0.71	0.63
	Liberal	-	-	-
MIXED	Baseline	0.42	0.45	0.54
	Probable	0.58	0.68	0.66
	Optimisation	0.51	0.58	0.59
	Liberal	-	-	-

Source: own research.

Although the expected value and certainty equivalent synthetically reflect the effects of changes predicted in individual scenarios, the scope of their variation plays a key role from the perspective of stability of financial performance. Table 7 includes information on the value of the coefficient of variation of income for individual models and scenarios. The presented data on variation were obtained with the use of the Monte Carlo simulation based on 10 000 trials. From the presented comparison it follows that the change in the conditions of the surrounding of farms, from the baseline scenario to the probable scenario, would cause a clear increase in the coefficient of variation for all model holdings (the highest in the case of small mixed holdings and the lowest for large pig holdings). It should be noted that mixed holdings are characterised by the lowest coefficient of variation against other types of farming in all economic size groups, which implies a favourable impact of diversification on income stabilisation. This effect may be observed for all scenarios, but assuming the implementation of optimisation, the coefficients of variation for mixed farms reached values very similar to crop farms (which as a result of optimisation became more diversified and for which the coefficients fell below the level noted for the baseline scenario). Because of the negative level of expected value of income, Table 7 does not cover coefficients of variation for the liberal scenario. The obtained model results do not give grounds for clear-cut identification of the economic size groups for which the income variation was higher. Observations showed that in the case of crop, cattle and mixed holdings larger farms are characterised by higher variation for most of the considered scenarios, and in the case of pig holdings the interrelation was reverse.

The effect of changes in stability of farming entailed in implementation of individual scenarios is even stronger than changes in the co-efficient of variation, reflected by the percentage of years at a loss (recorded as a result of the Monte Carlo simulation for 10 000 trials). It can be assumed that, from the perspective of sustainability of farms, this index is much more discriminatory than the mean values (e.g. expected value). Many years of negative results mean a threat for the functioning of farms. The comparison contained in Table 8 indicates that in the case of the baseline scenario the percentage of years noting a negative financial result does not exceed few percent for most of the farms. The worst, from this perspective, are the results of pig holdings that were characterised by the highest share of years at a loss. This observation should be linked to the existence in the pig market of a relatively sustainable phenomenon termed the "pork cycle" (Hamulczuk 2006). At the same time, it should be noted that there is a quite substantial difference in the percentage of years at a loss between large and small pig holdings (over 12% for economic size of EUR 4-25 thousand and 5.4% in the model for a farm of standard output at > EUR 100 thousand). This difference suggests that small pig holdings are more at risk of negative results than larger farms. This observation does not pertain to farms of other type of farming groups, where in the baseline scenario the percentage of years at a loss is greater than for farms of larger economic size, and this happens at absolutely lower frequency of losses than for pig holdings. Relatively higher percentage of losses for larger farms should be linked to them being more burdened with fixed costs which follows, for instance, from more frequent investments generating, e.g., higher costs of depreciation, loans and maintenance of fixed assets. At a relatively low variation (baseline scenario), higher fixed costs cause more frequent drops of income below zero. When the level of risk is higher (especially for the liberal scenario), for all types of farming, the largest farms note the lowest frequency of losses. But, in the context of the conducted analysis, the changes in the percentage of years at a loss between the baseline, and probable and liberal scenarios seem to be especially important. The emergence of conditions described under the probable scenario would cause a rise in the number of years at a loss by several to several dozen percentage points, which is an undeniable evidence of a risk growth and deterioration in the conditions of agricultural production, but the scope of the changes can also be considered as relatively "mild" (the value of the discussed index at 10% means that the loss appeared, on average, once every 10 years). Such a statement seems the more justified that implementation of the optimisation scenario allows for rather clear reduction in the negative effect stemming from external conditions (the scope of the reduction depends on the crop structure – it gives the greatest effect for crop and mixed holdings, and the lowest for the cattle holdings). Most of the farms would get into much greater difficulties if the conditions described in the liberal scenario had become a fact. Without adjustment changes, it would mean no possibility of further existence for most of them, since the percentage of years at a loss would be close to 100% (losses nearly every year). The strongest effects of liberalisation would be noted for crop and mixed farms which are reliant on direct payments to the greatest extent. The consequences would be the least severe for pig holdings which even now conduct activity very little dependent on support.

Table 8

The percentage of years noting a negative agricultural income (Monte Carlo simulation, 10 000 trials)

Type of farming	Scenario	Economic size (SO in EUR thousand)		
		EUR 4-25 thousand	EUR 25-100 thousand	> EUR 100 thousand
		% of observations		
CROP	Baseline	2.8	4.3	0.8
	Probable	10.1	13.2	12.5
	Optimisation	3.5	6.3	8.6
	Liberal	96.1	93.4	90.3
CATTLE	Baseline	0.2	1.7	5.6
	Probable	5.5	12.6	11.9
	Optimisation	4.0	11.1	11.2
	Liberal	50.0	46.0	39.2
PIGS	Baseline	12.2	5.8	5.4
	Probable	18.1	10.9	8.0
	Optimisation	15.6	9.2	7.4
	Liberal	72.8	20.0	14.7
MIXED	Baseline	0.7	1.6	4.0
	Probable	20.8	7.0	7.5
	Optimisation	11.8	4.3	5.5
	Liberal	99.4	82.9	43.5

Source: own research.

Table 9

The potential responses of farmers to a drop in income of more than 30% of the expected value

Responses	Type of farming				Economic size			Total
	cattle	pigs	mixed	crop	EUR 4-25 thousand	EUR 25-100 thousand	> EUR 100 thousand	
I will limit living expenses and continue farming as before	11.9	10.0	12.1	9.2	11.7	15.3	11.6	12.1
I will limit the planned investments	17.7	16.7	15.0	16.9	11.7	22.8	31.0	13.5
I will extend the area of the farm	3.5	4.3	4.0	7.2	4.1	7.0	11.7	4.6
I will increase the number of livestock units	9.5	9.5	5.4	3.7	6.2	13.1	4.6	7.0
I will consider a change in the type of farming	13.1	14.5	17.9	20.0	16.4	15.8	21.3	16.5
I will try to extend/start non-agricultural production	10.7	14.2	16.6	13.8	14.3	13.9	13.7	14.2
I will start/extend off-farm work	11.0	11.4	13.7	12.4	13.4	7.5	3.1	12.5
I will resign from commercial agricultural activity and sell or lease the land	6.4	5.8	6.4	6.6	7.2	2.7	3.0	6.5
The farm is not my main source of income and so I will not have to change anything	10.8	10.0	7.3	7.7	10.8	1.3	0.0	9.4
I plan to cease farming in the nearest future anyway	5.5	3.7	1.1	2.5	4.1	0.4	0.0	3.6
I will move to the city	0.1	0.0	0.4	0.0	0.1	0.3	0.0	0.1

Source: own research.

The results of achieved model solutions were supplemented with an analysis of possible responses of farmers to changes in the agricultural surroundings producing a drop in income of more than 30% of the value from former years (research carried out on a sample of nearly 600 farms keeping the FADN accountancy – details concerning the principles of sample selection were presented in another paper (cf. Sulewski 2014)). In general, the most often responses were “changes in type of farming" (16.5% of responses) (Table 9), "starting up or extending agricultural activity" (14.2%), and "reduction in planned investments" (13.4% of responses). The least often options turned out to be two opposite actions, i.e. "resignation from production" (6.5%) and "extension of farms" (on average, 4.6% of responses). On the basis of the obtained answers, it can thus be stated that deterioration of the situation will probably incline farmers to introduce changes into the production structure and limit the planned investments. Given the solutions achieved in the models for the optimisation scenario, it can be assumed that these changes may be sufficient to effectively limit the consequences of negative processes that were discussed in the initial part of the paper. At this point, it should be mentioned that, according to the research of Kopiński et al. (2013) and Krasowicz (2009), the organisational factors may influence agricultural production to a greater extent than natural conditions (including weather).

Conclusions

On the basis of the literature review it may be stated that the conditions for functioning of agriculture, given climate, market and institutional changes, will probably deteriorate in the future. On the global scale, the impact of the changes on agriculture will be diverse. As for Europe, climate change will probably improve the conditions in the northern countries and deteriorate them in the south. Trade liberalisation in agricultural products and reforms of the Common Agricultural Policy partially related thereto will probably lead to a growth in variation in agricultural markets in the next years. But it can be assumed that, just like in the past, subsequent reforms will be linked to simultaneous implementation of stabilisation mechanisms at the level of income. The implementation of the regulation on the establishment of the Income Stabilisation Tool (Regulation 2013) to the EU legislation may be treated as a manifestation of such measures. It also seems justified to state that the EU agricultural policy as regards subsidisation of farms will focus exceedingly more on support to risk management.

As for Poland, it can be assumed that the impact of climate change will be rather moderate – the change in yielding due to greater frequency of water stress periods will be the main problem. Increase in price volatility of crops in Poland will be a derivative of the situation on the global markets.

The model analysis showed that the existence of conditions described in the probable scenario will result in a growth in income variation and decrease in their expected value. However, the level of these changes will not be too high and the implementation of adjustments to the production structure may allow for quite effective minimisation of the impact of the negative processes on the level of individual agricultural holdings. Because of a rather strong dependence of agricultural income on the support in the form of direct payments the implementation of the liberal scenario would have much more serious consequences for the agricultural holdings. At present, such a scenario seems to be little likely, but its existence would undoubtedly cause an economic shock of institutional background.

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