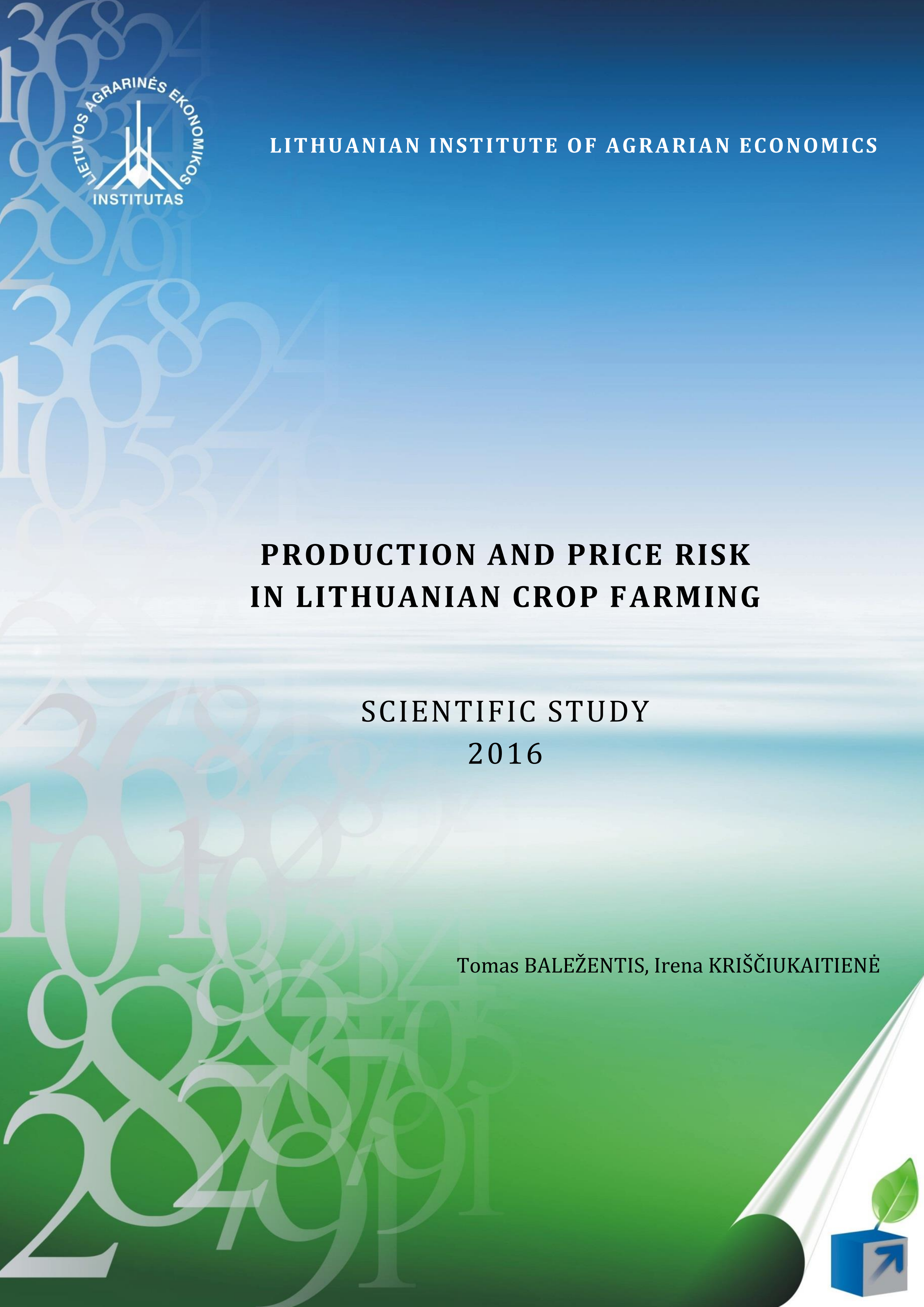

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PRODUCTION AND PRICE RISK IN LITHUANIAN CROP FARMING

SCIENTIFIC STUDY

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ABSTRACT

Agricultural sector requires analysing and managing multiple risks as agricultural production might be affected to a number of unfavourable institutional, economic and environmental factors. This study aims to identify the patterns of production and price risk in Lithuanian crops farming. Specifically, we look at two interrelated types of risk and their impacts on farm revenue. The following tasks are, therefore, set: 1) to define the methods for the analysis of insurance premium and changes in the revenue; 2) to describe the main spatial and temporal trends in Lithuanian crop farming; 3) to estimate the insurance premia for main crops and regions; 4) to analyse factors influencing revenue change. The study applies linear moving averages for analysis of trends in yields and prices. Insurance premia are modelled by fitting statistical distributions via the Maximum Likelihood. The changes in revenue are decomposed by means of Logarithmic Mean Divisia Index. The research covers years 2000-2015. The analysis is carried out at the county level and covers 10 counties.

The period of 2000-2015 marked significant changes in terms of both cropping patterns and extent in Lithuania. The most evident trend is the increase in area sown from 1.2 million ha in 2000 up to 1.7 million ha in 2015. The highest probabilities of yield loss were observed for maize, winter barley, and spring triticale. The results indicate that maize, buckwheat, winter barley, and winter rape show the highest production risk as represented by the relative insurance premia. The spatial differences in insurance premia were also observed. The results of the index decomposition analysis suggested that the effects of the area sown, the yield trend, and the price trend were the most important in driving the crop revenue up during 2000-2015. However, different patterns can be observed for the sub-periods of 2000-2006 and 2006-2015. Crop-wise analysis implied that winter wheat, spring wheat, winter rape, and spring rape offered the most important contributions the change in the total crop revenue. Region-wise analysis also enabled to identify regions that were most important in driving the total crop revenue up.

The study is organised as follows: Section 1 presents the methods used, namely trend modelling, distribution modelling, and IDA. Section 2 describes the dynamics in cropping patterns in Lithuania during 2000-2015. Section 3 presents the estimates of production risk. Finally, Section 4 brings forward the results of the IDA.

Keywords: risk; insurance premium; LMDI; index decomposition analysis; crop farming; Lithuania.

SANTRAUKA

GAMYBOS IR KAINŲ RIZIKA LIETUVOS AUGALININKYSTĖS SEKTORIUJE

Žemės ūkio sektoriuje yra svarbu analizuoti ir valdyti įvairaus pobūdžio riziką, nes žemės ūkio produktų gamyba gali būti paveikta žalingų institucinių, ekonominių ir aplinkos veiksnių. Šio tyrimo tikslas – nustatyti gamybos operacijų ir rinkos rizikos dėsningumus Lietuvos augalininkystės sektoriuje. Tyrime sprendžiamos dvi tarpusavyje susijusios problemos: nustatoma rizika ir jos poveikis augalininkystės sektoriaus pajamoms. Atsižvelgiant į tyrimo tikslą, nustatyti šie uždaviniai: 1) aptarti draudimo įmokos (premijos) ir pajamų pokyčių analizės metodus; 2) apibūdinti pagrindines Lietuvos augalininkystės sektoriaus tendencijas regioniniu ir chronologiniu aspektais; 3) įvertinti draudimo įmokas skirtingiems augalams ir regionams; 4) ištirti pajamų pokyčių veiksnius. Tyrime taikomas tiesinis slankiųjų vidurkių metodas, kurio pagalba nustatomos augalų derlingumo ir kainų tendencijos. Draudimo įmokos nustatomos įvertinant statistinius skirstinius maksimalaus tikėtinumo metodu. Pajamų pokyčiai išskaidomi taikant logaritminio vidurkio Divisia indeksą. Tyrimas apima 2000–2015 m. Analizė atliekama apskrities lygmeniu (nagrinėjama 10 apskričių).

Tyrimo rezultatai rodo, kad 2000–2015 m. Lietuvos augalininkystės sektoriuje vyko reikšmingi pokyčiai tiek pasėlių struktūros, tiek ūkininkavimo masto požiūriu. Akivaizdžiausia tendencija yra pasėlių ploto padidėjimas nuo 1,2 mln. ha 2000 m. iki 1,7 mln. ha 2015 m. Nustatyta, kad didžiausia derlingumo sumažėjimo tikimybė stebima kukurūzams, žieminiams miežiams ir vasariniams kvietrugiams. Tyrimo rezultatai rodo, kad kukurūzai, grikiai, žieminiai miežiai ir žieminiai rapsai pasižymi didžiausia gamybos operacijų rizika, kuri nustatyta pagal santykines draudimo įmokas. Taip pat buvo stebima regioninė draudimo įmokos dydžio sklaida. Indeksinio išskaidymo analizė atskleidė, kad 2000–2015 m. augalininkystės sektoriaus pajamų pokyčiams didžiausią įtaką turėjo pasėlių ploto pokyčiai ir derlingumo bei kainų tendencijos. Pažymėtina, kad 2000–2006 m. ir 2006–2015 m. yra būdingi skirtingi pajamų pokyčių dėsningumai. Lyginant skirtingus augalus nustatyta, kad kviečių ir rapsų auginimo pokyčiai daugiausia lėmė pajamų pokyčius. Regioninė analizė taip pat leido nustatyti regionus, kurie buvo svarbiausi augalininkystės sektoriaus pajamų pokyčių požiūriu.

Studiją sudaro keturi skyriai. Pirmajame skyriuje pristatoma tyrimo metodika (trendų modeliavimas, statistinių skirstinių modeliavimas, indeksinio išskaidymo analizė). Antrajame skyriuje apibūdinami pasėlių kaitos dėsningumai Lietuvoje 2000–2015 m. Trečiajame skyriuje pateikiami gamybos operacijų rizikos analizės rezultatai, o ketvirtajame – pajamų pokyčių indeksinio išskaidymo analizės rezultatai.

Raktiniai žodžiai: rizika; draudimo įmoka; logaritminio vidurkio Divisia indeksas; indeksinio išskaidymo analizė; augalininkystė; Lietuva

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ABBREVIATIONS

AAI	aggregate advantage index
CAP	Common Agricultural Policy
CV	coefficient of variation
DCV	downside coefficient of variation
EU	European Union
HHI	Herfindahl-Hirschman index
IDA	index decomposition analysis
LMA	linear moving average
LMDI	logarithmic mean Divisia index

INTRODUCTION

Motivation. Agricultural production might be affected by a number of risks, induced by institutional, economic and environmental factors. As agriculture is an essential activity in terms of meeting food security objectives, governments worldwide encourage support risk mitigation strategies there. Furthermore, agricultural producers tend to increase their scale of operation and degree of mechanization with stronger global integration and competition. These developments require considerable investments into capital assets, which are facilitated by credits. Consequently, farmers, government institutions, and financial intermediaries all have become more concerned over stability of agricultural income.

There are two general types of risk affecting the revenue of agricultural business, namely production and price risks. Production risk is mainly related to random fluctuation in yields due to environmental factors, i.e. yield risk. Among the possible measures for yield risk mitigation, crop insurance plays an important role. Following traditional crop insurance approach, an indemnity is paid out in case crop is damaged by predefined natural events within a farm. In this case information asymmetry needs to be reduced by means of damage assessment, which inflates the operational costs of an insurer. In order to alleviate these costs, governments (e.g., EU and USA) have been subsidizing the crop insurance (Goodwin, Mahul, 2004; OECD, 2009, 2011). One can distinguish between loss insurance (due to hail or other natural hazard) and yield insurance (Vilhelm et al., 2015). Leblois and Quirion (2013) argued that insurance based on meteorological indices constitutes an alternative to traditional insurance approach as indemnity is paid out due to region-wide meteorological fluctuations in the former case. Bielza et al. (2007) presented a survey of agricultural risk management strategies across EU Member States. As regards price risk, it has increased due to abolishment of price subsidies (Anton, Kimura, 2009). Consequently, the mitigation of risk has become increasingly dependent on farmers decisions. Therefore, it is important to combine different strategies for the agricultural risk management depending on prevailing types of risk and attitudes of decision makers.

Once most relevant types of agricultural risk have been identified, the estimation of risk level constitutes the focal issue for research on risk managements. Statistical methods are then applied to model the risk. In particular statistical distributions are fitted to observed data on agricultural production. This can be done on farm, regional and/or national level. Indeed, it has been shown that the higher level of aggregation induces lower variation of performance indicators and, in turn, agricultural risk (OECD, 2009). In order to identify the underlying trends in agricultural risk, it is, therefore, important to apply statistical methods at regional and/or farm level.

Research problem. The share of crop production in gross agricultural production has exceeded 50 percent in Lithuania since the last decade of the 20th century (Statistics Lithuania, 2016). The economic incentives regarding crop production and its structure have been shaped by the CAP since accession to the EU. Climate change has also affected crop yields (Povilaitis et al., 2013). In addition, crop insurance has been introduced in Lithuania. Therefore, it is important to establish a monitoring system for grasping the main trends in agricultural risk in crop farming.

Certain aspects for the agricultural risk have been analysed in Lithuanian yet now modelling of production risk has been carried out at the regional level. These studies mainly followed the two strands, namely construction of composite indicators and decomposition of performance indicators. Girdziute et al. (2014) combined multiple indicators by means of factor analysis to gauge the level of agricultural risk in Lithuania. Streimikiene et al. (2016) applied benefit of the doubt model for analysis of financial risk in Lithuanian family farms. The latter research relied of farm level data from Farm Accountancy Data Network. Kozlovskaja (2013) focused on factors affecting revenue for different crops. It turned out that price risk was more important factor if compared to yield risk. The lowest variation in revenue was observed for rape and potatoes. Peleckis et al. (2015) analysed the practice of crop insurance in Lithuania from viewpoints of government, farmers and insurers. Baležentis and Baležentis (2011) employed LMDI model to decompose the changes in grain harvest. Baležentis and Kriščiukaitienė (2015) applied Shapley value decompose the changes in milk revenue in Lithuania in terms of milk quantity, fat contents and producer price. Noteworthy aforementioned studies did not consider such downside risk measures as semivariance (Hogan, Warren, 1974). Furthermore, distribution-based measures of risk were not estimated and, hence, the probability of hazard remained ignored. As regards the level of aggregation, there is a need for regional (county-level) analysis.

Methodological issues. Measurement of the risk aims to quantify the possibility of deviations from the expected level of an indicator analysed. However, only deviations below expected level of yield and/or price can be considered when estimating agricultural risk. Several types of measures are available for this purpose (Goodwin, Mehul, 2004). First, the moments of statistical distribution (i.e., average, variance, skewness and kurtosis) can be applied to describe the variation of yield or other variable. Second, statistical distribution can be fitted to observed time series. This can be done by two approaches: parametric and non-parametric. Parametric approach seeks to optimise parameters of predefined statistical distributions via maximum likelihood or other methods (cf. Gerlt et al., 2014; Kobus, 2012; Zhang, Wang, 2010). Non-parametric approach applies kernel smoothing to estimate underlying distribution without specific assumption regarding its shape. The latter approach was applied by Goodwin and Ker (1998), Ker and Goodwin (2000), Zheng et al. (2014). Estimation of agricultural risk requires the calculations of expected values yields and/or prices. These can be obtained by applying different estimators. For instance, Finger (2013) used ordinary least squares, method of moments and the Theil–Sen estimators, whereas Zhang and Wang (2010) employed LMA technique. Yet another group of models rely on mathematical programming and seek to maximize profit and minimize agricultural risk (Gómez-Limón et al., 2003; Kimura et al., 2010), thereby allowing to account for the risk aversion. In general, Yuan et al. (2015) classify risk measures into probability-based and indicator-based ones.

The impact of price and yield fluctuations on farm revenue can be analysed by applying IDA. Specifically, IDA enables to decompose the changes in revenue with respect to multiple factors. The key principles of IDA were discussed by Ang (2004, 2005). Indeed, the latter approach was mainly applied in energy economics (Xu, Ang, 2013; Liu et al., 2016; Dai et al., 2016; Wang et al., 2016; Li et al., 2016). Preferably, IDA should satisfy the properties of perfect decomposition (no residual term remains after the decomposition), time reversal (for any two periods either of them can be chosen as base period with no impact on results) and path independence (the results are not affected by the order factors enter into the model). LMDI and Shapley value are two methods for the IDA satisfying most of the aforementioned properties. LMDI was defined by Ang et al. (1998) and Ang and Liu (2001). Wu et al. (2016) applied LMDI for phosphorus flow management. Xu et al. (2015) employed LMDI for water footprint analysis. Robaina-Alves and Moutinho (2014) used the same method to analyse energy-related GHG emissions in agriculture. As it was already said, Baležentis and Baležentis (2011) and Baležentis and Kriščiukaitienė (2015) applied LMDI and Shapley, respectively, to analyse intensive and extensive development of Lithuanian agriculture.

This study aims to identify the patterns of production and price risk in Lithuanian crops farming. Specifically, we look at two interrelated types of risk and their impacts on farm revenue. The following tasks are, therefore, set: 1) to define the methods for the analysis of insurance premium and changes in the revenue; 2) to describe the main spatial and temporal trends in Lithuanian crop farming; 3) to estimate the insurance premia for main crops and regions; 4) to analyse factors influencing revenue change.

The study applies LMA for analysis of trends in yields and prices. Insurance premia are modelled by fitting statistical distributions via the Maximum Likelihood. The changes in revenue are decomposed by means of LMDI. Noteworthy, we combine LMDI and LMA to measure the impact of random deviations of prices and yields. The research covers years 2000-2015. The analysis is carried out at the county level and covers 10 counties. The data come from Statistics Lithuania (2016).

The study is organised as follows: Section 1 presents the methods used, namely trend modelling, distribution modelling, and IDA. Section 2 describes the dynamics in cropping patterns in Lithuania during 2000-2015. Section 3 presents the estimates of production risk. Finally, Section 4 brings forward the results of the IDA.

1. METHODS

This section presents the quantitative methods applied for the analysis of production risk and variation in crop revenue. LMA is applied for trend estimation. Production risk can be analysed in terms of CV and risk probability-based risk measures (insurance premium). Finally, IDA is presented as a tool for decomposition of changes in the total crop revenue.

1.1. Trend analysis

Risk analysis requires estimation of the expected value of a variable of interest. This can be done by applying trends of different orders, autoregressive-moving average models, splines or kernel smoothing (Goodwin, Mahul, 2004; Ye et al., 2015). Practically, insurance premium can be estimated by considering a simple average of the previous 4-10 years.

In this study, we follow approach of Zhang and Wang (2010). Specifically, LMA is applied for the estimation of expected yields and prices. LMA combines linear regression and moving average approach. Indeed, the use of moving average allows for non-linearity of the resulting trend.

LMA is related to moving average in that the sample is divided into sub-samples of fixed length, which is referred to as step. Let us denote the size of step as k. Therefore, a sample (time series) is divided into $n-k+1$ sub-samples, where n is the number of observations within a sample.

Let $i=1,2,\ldots,n-k+1$ be the index of sub-samples and t denote time period falling within a certain sub-sample. Then, the linear trend is fitted for each sub-sample:

$$y_i(t)=a_i+b_i t+e_i^t\,, \tag{1}$$

where $y_i(t)$ is variable of interest (e.g. yield, price) and t represents different time periods:

$$t=\begin{cases}1,2,\ldots,k, & i=1,\\ 2,3,\ldots,k+1, & i=2,\\ \vdots & \vdots\\ n-k+1,n-k+2,\ldots,n, & i=n-k+1\end{cases}. \tag{2}$$

Therefore, each observation falls within different number of sub-sample, i.e. observations at the beginning and at the end of research period fall within fewer sub-samples than those located at the middle of the time series. The exact number of fitted values for each observation depends on sample size and step size. Specifically, let q be the number of fitted values for each observation. Then, q is defined as follows:

$$q = \begin{cases} 1,2,\ldots,\underbrace{k,\ldots,k}_{n-2(k-1)},\ldots,2,1, & k \le \dfrac{n}{2}, \\ 1,2,\ldots,\underbrace{n-k+1,\ldots,n-k+1}_{2k-n},\ldots,2,1, & k > \dfrac{n}{2} \end{cases}. \tag{3}$$

Finally, the trend estimated by considering fitted values for time series point. Specifically, the average of q values is computed:

$$\hat{\hat{y}}(t) = \frac{1}{q}\sum_{j=1}^{q} \hat{y}_j(t), \tag{4}$$

where $\hat{\hat{y}}(t)$ is the trend of the t-th time period and $\hat{y}(t)$ is the fitted value from Eq. 1.

1.2. Indicators of variation and advantage

Basic statistical measures of risk include mean, variance, skewness and kurtosis. These can be applied to describe the shape of underlying distribution of a variable of interest (e.g., prices or yields). Noteworthy, gains in yields or prices resulting in levels thereof exceeding the expected values should not be considered as risk. Therefore, downside measures can be applied to assess the risk.

CV can be used as a dimensionless measure for comparison of several time series. For instance, it can be applied for comparison of variation in yields or prices across different region. CV is obtained as follows:

$$CV = \frac{s_y}{\bar{y}}, \tag{5}$$

where s_y and $\bar{y}$ are standard deviation and average of random variable y. Standard deviation is calculated as:

$$s_y = \left(\frac{1}{n-1}\sum_{t=1}^{n} \left(y(t) - \bar{y} \right)^2 \right)^{1/2}. \tag{6}$$

In order to disregard values exceeding the expected one, we employ the idea of semi variance (Hogan, Warren, 1974). As a result, the downside CV can be constructed:

$$CV_d = \frac{s_y^d}{\bar{\hat{y}}}, \tag{7}$$

where $\bar{\hat{y}}$ is the average of the trend values (cf. Eq. 4) and s_y^d is the downside standard deviation. The latter variable is defined in the following manner:

$$s_y^d = \left(\frac{1}{n-1} \sum_{t=1}^{n} \left(\min\left[y(t) - \hat{y}(t), 0 \right] \right)^2 \right)^{1/2}. \tag{8}$$

Therefore, the downside CV measures the degree of the deviations below the expected value. In this case, the expected value is defined as an LMA estimate.

Crop structure and yields tend to vary across different region due to climatic and economics conditions. Accordingly, some regions are more important in terms of production of a certain crop than the others. In order to relate agricultural risk to importance of regions, it is essential to quantify the comparative advantage for regions and crops.

Let i and j be the indexes for crops and regions respectively. Then, let a_{ij} denote area sown for the i-th crop in the j-th region (county). Furthermore, the total area sown for the i-th crop is denoted by $A_i = \sum_j a_{ij}$, the total area sown for the j-th region (county) is denoted by $A_j = \sum_i a_{ij}$, and the total area sown for the whole country is denoted by $A = \sum_j \sum_i a_{ij}$. Similarly, let h_{ij} denote harvest for the i-th crop in the j-th region. In addition, the total harvest for the i-th crop is denoted by $H_i = \sum_j h_{ij}$.

The scale advantage index compares the share a certain crop area within a certain region to that within the whole country. Denoting the scale advantage index by SA_{ij}, one can define it as follows:

$$SA_{ij} = \frac{a_{ij} / A_j}{A_i / A}, \tag{9}$$

where i and j are the indexes for crops and regions respectively. Therefore, $SA_{ij} \geq 1$ indicates region j specializes in production of crop i. On the contrary, $SA_{ij} \leq 1$ indicates region j does not specialize in production of crop i.

The comparative advantage index compares the yield of a certain crop in a certain region to the national average yield. After denoting the comparative advantage index by CA_{ij}, one can define it as follows:

$$CA_{ij} = \frac{h_{ij}/a_{ij}}{H_i/A_i}, \tag{10}$$

where i and j are the indexes for crops and regions respectively. Again, $CA_{ij} \geq 1$ indicates region j enjoys comparative advantage in production of crop i. On the contrary, $CA_{ij} \leq 1$ suggests region j has no comparative advantage in production of crop i.

The two indices given in Eqs. 9-10 can be combined into the aggregate advantage index. The latter is a simple geometric average:

$$AA_{ij} = \left(CA_{ij} \cdot SA_{ij}\right)^{1/2}. \tag{11}$$

Regions showing aggregate advantage in production of crop i exhibit $AA_{ij} \geq 1$. On the opposite, $AA_{ij} \leq 1$ implies region j has no aggregate advantage in production of crop i.

1.3. Modelling the relative insurance premium

Modelling of insurance premium rests on the three key elements: yield loss ratio, statistical distribution and calculation of the insurance premium. Yield loss ratio describes fluctuations in yield with respect to long-run trend. Such a measure can also accommodate price or other variable of interest. Statistical distribution allows to estimate probabilities of decrease in yield or other variable. Once the distribution function is known, insurance premium can be calculated. Each of these elements is discussed below.

Yield loss ratio

Yield risk can be estimated by considering deviations from the trend. The deviation can be obtained as follows:

$$y_d(t) = y(t) - \hat{y}(t). \tag{12}$$

Goodwin and Ker (1998) argued that the standard deviation of the de-trended yield $y_d(t)$ is proportional to the average yield. Deng et al. (2002) and Zhang and Wang (2010) proposed using the relative stochastic variation as a measure of the risk:

$$y_r(t) = \frac{y(t) - \hat{y}(t)}{\hat{y}(t)}. \tag{13}$$

Therefore, $y_r(t)$ is independent of the average level of the time series and can be used for comparisons across space and time. The latter indicator measures relative deviations from the trend due to short-run shocks.

Statistical distribution

In the previous sub-section, measures of standard deviation were discussed. However, they cannot fully describe the variation in yields or prices in case underlying distribution deviates from the normal (Gaussian) one. Specifically, the value of CV tells little about the probability of yield loss of specific magnitude. What is more, the latter variable becomes even less informative in case of non-normal distribution. Therefore, statistical distributions often applied to measure the risk (Goodwin, Mahul, 2004). The densities for variables of interest can be estimated either parametrically or non-parametrically. The non-parametric approach requires no assumptions about the shape (family) of the underlying distribution (Ker, Goodwin, 2000). However, it performs better for large samples. The parametric approach requires specification of density and/or distribution function. Then, required parameters are estimated via Maximum Likelihood or other methods. The parametric approach is more suitable for small samples. For instance, Zhang and Wang (2010) considered the beta, the Burr, the gamma, the Jonson, the logistic, the lognormal, the normal, the Rayleigh and the Weibull distributions. The Burr distribution appeared as the most preferable one when modelling wheat yield in Beijing, China. Kobus (2012) applied the normal, the gamma, the Burr and the generalized beta distributions for analysis of wheat yield in Poland. Indeed, the normal distribution had the best fit in the highest number of cases.

Given our time series include sixteen observations for years 2000-2015, we opt for parametric approach. Specifically, we apply the normal and the logistic distribution to model crop yield in the Lithuanian regions.

The normal (Gaussian) distribution is defined in terms of two parameters, mean μ and standard deviation σ. Its density function is

$$f(y;\mu,\sigma)=\frac{1}{\sigma\sqrt{2\pi}}e^{-\frac{1}{2}\left(\frac{y-\mu}{\sigma}\right)^2}. \tag{14}$$

The logistic distribution uses location parameter μ and scale parameter σ for the following density function:

$$f(y;\mu,\sigma)=\frac{e^{\frac{y-\mu}{\sigma}}}{\sigma\left(1+e^{\frac{y-\mu}{\sigma}}\right)^2}. \tag{15}$$

Parameters required for densities given in Eqs. 14-15 are estimated via the Maximum Likelihood. The resulting functions can be integrated to measure the risk of losses. The range of integration can be adjusted in order to estimate the risk of certain scale (Liu et al., 2006).

Insurance premium

The actuarially fair insurance premium should equal the expected loss (Goodwin, Mahul, 2004). Mathematically, the expected loss is defined as a product of probability that a loss occurs and the expected loss given that a loss occurs:

$$L = E\left(\max\left[\lambda u - y, 0\right]\right) = \Pr\left(y < \lambda u\right)\left(\lambda u - E\left(y \mid y < \lambda u\right)\right), \tag{16}$$

where L is the expected loss, λ is the coverage level, u is the expected insured yield and y is the observed yield. Eq. 16 considers actual and expected yields, but we seek to model the relative stochastic variation (Eq. 13). Therefore, we follow Zhang and Wang (2010) and assume the indemnity, I, is paid out in case the actual yield loss ratio (Eq. 13) exceeds the guarantee level. Then, the insurance premium, π, is defined as follows:

$$\pi = E\left(I\right) = E\left(u \cdot p \cdot \max\left[y_c - y_r, 0\right]\right), \tag{17}$$

where u is the expected insured yield, p is price per unit of yield, y_c is the guarantee yield level and is y_r is the actual yield loss ratio. Given we are interested in relative measures in risk, we ignore prices in further calculations. The relative premium, R, can be estimated as follows (Zhang, Wang, 2010):

$$R = \frac{E\left(I\right)}{u} = \int_{-1}^{y_c} \left(y_c - y_r\right) f\left(y_r\right) dy_r, \tag{18}$$

where $f(y_r)$ is the density function. We further assume $y_c = 0$, i.e., any deviation in actual yield below the expected one is covered by the insurance. The resulting measure of the risk indicates the expected yield loss. This can be used for the comparisons of risk across crops and regions.

1.4. Index decomposition analysis

Many economic phenomena can be explained in terms of multiple indicators representing intensive and extensive factors. In this case IDA can be applied to isolate the effects of particular factors. Specifically, the changes in the aggregate variables are decomposed in the terms associated with respective factors. In this study we decompose the changes in crop revenue into factors representing variation in areas sown, crop structure, yields and prices. LMDI, type I, is employed to implement IDA.

Furthermore, we include additional terms into the model accounting for random deviation from crop and yield trends estimated by means of LMA. By doing so, we are able to quantify the effects of long-term developments in yields (e.g., technological progress, introduction of more productive varieties) and prices (these are due to changes in the global commodity markets and increasing quality of domestic production). Below, we present the general IDA model and adapt it for the analysis of crop revenue.

The general IDA model based on LMDI was defined by Ang (2005). Let us consider aggregate variable *V* with *n* factors driving *V* over time. Let each factor be represented by respective variable from set $x_1, x_2, \ldots, x_n$. Assume the aggregate variable is composed of m sub–categories represented by index i. Therefore, the aggregate variable for the *i*–th sub-category is defined as follows: $V_i = \prod_{j=1}^{n} x_{ji}$. By summing these variables over sub-categories, one gets the IDA identity:

$$V = \sum_i V_i = \sum_i \prod_j x_{ji}, \tag{19}$$

where $i = 1, 2, \ldots, m$ and $j = 1, 2, \ldots, n$. Furthermore, the aggregate variable for the *i*–th sub-category in period 0 is defined as $V_i^0 = \prod_{j=1}^{n} x_{ji}^0$, whereas that in period *T* is given by $V_i^T = \prod_{j=1}^{n} x_{ji}^T$.

The changes in the aggregate variable can be decomposed additively or multiplicatively thus identifying absolute or relative contributions of different factors. The additive decomposition allows attributing the difference in the aggregate variable over the time to respective factors:

$$\Delta V = V^T - V^0 = \Delta V_{x_1} + \Delta V_{x_2} + \ldots + \Delta V_{x_n}. \tag{20}$$

In case of multiplicative decomposition, the following ratio is decomposed:

$$D = V^T / V^0 = D_{x_1} D_{x_2} \ldots D_{x_n}. \tag{21}$$

As one can note, the terms on the right–hand side are the effects associated with respective factors in Eq. 19.

The additive LMDI is implemented by distributing the difference in the aggregate variable for the *i*-th sub-category across the factors by considering weights defined as ratios of logged rates of growth in factor variables to that in the aggregate variable for the *i*-th sub-category:

$$\Delta V_{x_k} = \sum_i \frac{V_i^T - V_i^0}{\ln V_i^T - \ln V_i^0} \ln\left(\frac{x_{ki}^T}{x_{ki}^0}\right), \tag{22}$$

As for multiplicative LMDI, the weights are further normalised by the ratio of absolute change in the aggregate variable over the logged rate of growth in it.

$$D_{x_k} = \exp\left(\sum_i \frac{\left(V_i^T - V_i^0\right)/\left(\ln V_i^T - \ln V_i^0\right)}{\left(V^T - V^0\right)/\left(\ln V^T - \ln V^0\right)} \ln\left(\frac{x_{ki}^T}{x_{ki}^0}\right)\right), \tag{23}$$

where $k = 1, 2, \ldots, n$. The presented equations describe the general case of the IDA and LMDI. In order to analyse specific phenomenon one needs to establish a corresponding IDA identity. A set of multiplicatively related indicators needs to be established.

In this study we consider the changes in crop revenue for major crops (wheat, triticale, rye, barley, oats, buckwheat, mixed cereals, maize, legumes, rape and potatoes) across the ten counties. Crop revenue is defined as the product of the harvest and price for each crop and county. Crop prices are unified across the counties. The revenue is decomposed into seven components, which can be classified into three groups: 1) area effect, 2) yield effect and 3) price effect. Area effect is basically represented by a single variable, namely total area sown for the whole country. Therefore, the latter variable captures the change in revenue due to the overall change in the area sown, with other factors remaining fixed. The yield effect can be broken down into the two parts, i.e., structural yield effect and pure yield effect. Structural yield effect accounts for the yield changes due to shifts in crop distribution across and within counties. Pure yield effect measures the variation in crop revenue induced by both long-term developments and random shocks in county-specific crop yields. Similarly, price effect accounts for changes in crop revenue due to both long-term developments and random shocks in crop prices at the national level. Therefore, the two components involving random shocks are associated with yield and price risks.

In order to formally present the IDA model for the decomposition in crop revenue, let indexes i and j denote crops and regions respectively. Then, let a_{ij} and h_{ij} denote area sown and total harvest for the i-th crop in the j-th region (county). Furthermore, the total area sown for the j-th region (county) is denoted by $S_j = \sum_i a_{ij}$, and the total area sown for the whole country is denoted by $A = \sum_j \sum_i a_{ij}$. Accordingly, the crop revenue, R, can be decomposed into the seven factors:

$$R = \sum_i \sum_j A \cdot S_j \cdot M_{ij} \cdot Y_{ij}^* \cdot Y_{ij} \cdot P_{ij}^* \cdot P_{ij} \;, \tag{24}$$

where

A is the country-wide total area sown,

S_j is the share of area sown for the j-th county,

M_{ij} is the share of area sown under the i-th crop within the j-th county,

Y_{ij}^* is the fitted yield for the i-th crop within the j-th county,

Y_{ij} is the ratio of the observed yield over the fitted one for the i-th crop within the j-th county,

P_{ij}^* is the fitted price for the i-th crop within the j-th county,

P_{ij} is the ratio of the observed price over the fitted one for the i-th crop within the j-th county.

Note that the fitted value for yields and prices are obtained by means of the LMA (see Section 1.1). In addition we do not control for county-specific prices and assume they are equal across counties. The proposed approach should consider marketing year, however, our application uses calendar year due to data availability in Lithuania.

Considering the base and current and time period denoted by 0 and T respectively, the change inn crop revenue can be additively decomposed as follows:

$$\Delta R = R^T - R^0 = \Delta R_A + \Delta R_S + \Delta R_M + \Delta R_{Y^*} + \Delta R_Y + \Delta R_{P*} + \Delta R_P . \tag{25}$$

The respective effects $\Delta R_A, \Delta R_S, \Delta R_M, \Delta R_{Y^*}, \Delta R_Y, \Delta R_{P*}, \Delta R_P$ can be estimated by employing the following equations:

$$\Delta R_A = \sum_j \sum_i \bar{R}_{ij} \ln\left(A^T / A^0\right), \tag{26}$$

$$\Delta R_S = \sum_j \sum_i \bar{R}_{ij} \ln\left(S_j^T / S_j^0\right), \tag{27}$$

$$\Delta R_M = \sum_j \sum_i \bar{R}_{ij} \ln\left(M_{ij}^T / M_{ij}^0\right), \tag{28}$$

$$\Delta R_{Y*} = \sum_j \sum_i \bar{R}_{ij} \ln\left(Y_{ij}^{T*} / Y_{ij}^{0*}\right), \tag{29}$$

$$\Delta R_Y = \sum_j \sum_i \bar{R}_{ij} \ln\left(Y_{ij}^T / Y_{ij}^0\right), \tag{30}$$

$$\Delta R_{P*} = \sum_j \sum_i \bar{R}_{ij} \ln\left(P_{ij}^{T*} / P_{ij}^{0*}\right), \tag{31}$$

$$\Delta R_P = \sum_j \sum_i \bar{R}_{ij} \ln\left(P_{ij}^T / P_{ij}^0\right), \tag{32}$$

where $\bar{R}_{ij} = \dfrac{R_{ij}^T - R_{ij}^0}{\ln R_{ij}^T - \ln R_{ij}^0}$ and $R_{ij}^t = \sum_{i=1}^{m} a_{ij}^t y_{ij}^t p_{ij}^t, t = \{0, T\}$, with a_{ij}^t, y_{ij}^t, and p_{ij}^t being the area sown, yield, and price for the i-th crop within the j-th county, respectively.

In order to compare variables that are different in their absolute levels a multiplicative decomposition can be carried out. In this case, the rate of growth in aggregate variable is decomposed in terms of explanatory factors. Therefore, the multiplicative decomposition can be described as follows:

$$D = R^T / R^0 = D_A D_S D_M D_{Y*} D_Y D_{P*} D_P, \tag{33}$$

where:

$$D_A = \exp\left(\sum_j \sum_i \left(\bar{R}_{ij} / \bar{R}\right) \ln\left(A^T / A^0\right)\right), \tag{34}$$

$$D_S = \exp\left(\sum_j \sum_i \left(\bar{R}_{ij} / \bar{R}\right) \ln\left(S_j^T / S_j^0\right)\right), \tag{35}$$

$$D_M = \exp\left(\sum_j \sum_i \left(\bar{R}_{ij} / \bar{R}\right) \ln\left(M_{ij}^T / M_{ij}^0\right)\right), \tag{36}$$

$$D_{Y*} = \exp\left(\sum_j \sum_i \left(\bar{R}_{ij} / \bar{R}\right) \ln\left(Y_{ij}^{T*} / Y_{ij}^{0*}\right)\right), \tag{37}$$

$$D_Y = \exp\left(\sum_j \sum_i \left(\bar{R}_{ij} / \bar{R}\right) \ln\left(Y_{ij}^T / Y_{ij}^0\right)\right), \tag{38}$$

$$D_{P*} = \exp\left(\sum_j \sum_i \left(\bar{R}_{ij} / \bar{R}\right) \ln\left(P_{ij}^{T*} / P_{ij}^{0*}\right)\right), \tag{39}$$

$$D_P = \exp\left(\sum_j \sum_i \left(\bar{R}_{ij} / \bar{R}\right) \ln\left(P_{ij}^T / P_{ij}^0\right)\right), \tag{40}$$

where $\bar{R} = \sum_{i=1}^{m} \sum_{j=1}^{n} \bar{R}_{ij}$. Note that the rate of growth (rather than a factor) can be decomposed in an additive manner by taking logs of both sides of Eq. 33.

2. CROPPING TRENDS AND PATTERNS

This section focuses on the trends in the key factors of the crop revenue. Specifically, the changes in crop areas represent the extensive development, whereas changes in the spatial distribution captures the structural shifts related to aggregate yield. Crop yields describe the technical change within different regions. AAI is computed in order to reflect the changes in regional productivity and distribution of crop areas. In addition, the general trends in crop revenue are discussed.

2.1. The amount and structure of area sown

During 2000-2015, the area sown under the crops analysed (i.e., wheat, triticale, rye, barley, oats, buckwheat, mixed cereals, maize, legumes, rape and potatoes) has increased by some 41% from 1.187 million ha up to 1.676 million ha. The mean area sown was 1.315 million ha[1]. Fig. 1 below depicts the dynamics the total area sown in Lithuania. Note that there had been a decrease in the total area sown throughout 2000-2003 due to low prices and support. That period marked a decrease in areas sown of some 12% (from 1.187 million ha down to 1.046 million ha). However, the trend was reversed after Lithuania entered the EU and surpassed the initial level of year 2000 in 2006. Therefore, expansion of area sown has contributed to increase in crop revenue in Lithuania during 2003-2015. These developments have obviously been stimulated by increasing support payments under EU CAP.

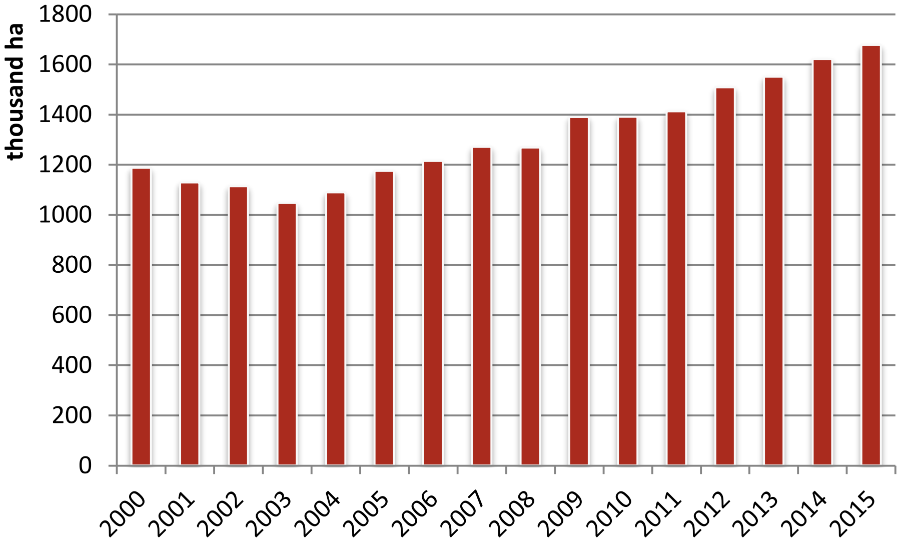

Fig. 1. Dynamics in the area sown under the crops analysed, 2000-2015

Looking at dynamics in areas sown across the counties, one can notice certain differences in absolute changes and relative growth. As regards the county ranking in terms in area sown, the same counties remained possessing the largest land

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[1] Statistics Lithuania, indeed, provides data on area harvested, yet the differences are not decisive and we assume that area sown corresponds to area harvested.

endowments during research periods. Šiauliai, Panevėžys and Kaunas counties are the largest one in regard to areas sown under crops covered by this research. More detailed analysis of changes in areas sown across counties is given in Table 1.

Šiauliai, Panevėžys and Kaunas counties were not only specific with the largest areas sown, but also showed high rates of growth in these. Indeed, the areas sown grew by 53-58% in the latter three counties. In Šiauliai county, the area sown under the crops analysed increased from some 232 thousand ha up to 360 thousand ha. As for Panevėžys and Kaunas counties the areas sown went up from 188 and 182 thousand ha to 296 and 279 thousand ha, respectively. Telšiai county showed the highest rate of growth of 71%. However, the area sown equalled 50 thousand ha and 85 thousand ha for 2000 and 2015, respectively, there. The lowest rate of growth was observed for Tauragė county (0.7%), where the area sown fluctuated at around 65 thousand ha during 2000-2015 (yet the values for the beginning and end of the research period were both equal to some 74 thousand ha). CVs for separate counties showed that these were quite similar in term of the magnitudes of variations in areas sown. More specifically, CVs for Alytus, Marijampolė and Tauragė counties varied in between 0.1 and 0.13. In case of Marijampolė, the lower value of CV was related to low volatility of the associated time series. As for Alytus and Tauragė, the lower variation was due to limited growth of the area sown. For the rest of counties, CVs varied in between 0.16 and 0.2. Among these, Utena and Vilnius counties exhibited the lowest rates of growth thereby suggesting high volatility of the corresponding time series. Therefore, the changes in the area sown differed in terms of directions and magnitudes across time periods and counties, which resulted in different impacts on crop revenue.

Even though all the counties showed positive rates of growth in areas sown during 2000-2015, these changes were uneven across counties. As a result, the importance of different counties changed in different directions. The highest increases in the shares of areas sown of almost 2% were observed for Šiauliai and Panevėžys counties. The total area sown in these two counties amounted to 35% and 39% of the national area sown under crops analysed in 2000 and 2015 respectively. Kaunas county showed somewhat lower rate of change in area sown, i.e. 1.3%. The share of Kaunas county in the national area sown constituted some 17% in 2015. Accordingly, Šiauliai, Panevėžys and Kaunas counties managed to increase their share in the national area sown and maintained growth in absolute terms. The decreasing shares in the national areas sown were observed for smaller counties. The steepest decreases were observed for Tauragė and Utena counties (-1.8 p.p. and -1.2 p.p. respectively). As a result, the share of Tauragė and Utena counties went down from some 12% to 9% during 2000-2015. Counties specific with the highest rate of decrease in the share of the national area sown showed the highest CVs for this indicator. These results indicate the counties changed their relative importance in terms of area sown thus contributing to change in aggregate yield due to different soil fertilities, landscapes and resource endowments. Higher level of the specialisation of a region might induce higher agricultural risk. The level of the specialisation can be measured in terms of shares of areas sown under different crops within a region. Besides crop-specific measures of specialisation presented in Section 1.2, we will also consider the general measure of the specialisation.

Table 1. The changes in the area sown under selected crops across counties of Lithuania, 2000-2015

	Alytus	Kaunas	Klaipėda	Marijampolė	Panevėžys	Šiauliai	Tauragė	Telšiai	Utena	Vilnius
	Area sown, ha									
2000	59518	182473	80249	139018	187965	231869	73617	49758	64706	117707
2015	70050	279254	96824	190400	296332	359601	74126	85154	71528	153025
Growth, %	17.7	53.0	20.7	37.0	57.7	55.1	0.7	71.1	10.5	30.0
Std. Dev.	5862	35671	11884	20080	43296	48956	6557	12797	10344	20348
Mean	57683	214075	74009	156433	227606	290163	64649	63376	53135	113711
CV	0.10	0.17	0.16	0.13	0.19	0.17	0.10	0.20	0.19	0.18
	Share in the national area sown, %									
2000	5.0	15.4	6.8	11.7	15.8	19.5	6.2	4.2	5.5	9.9
2015	4.2	16.7	5.8	11.4	17.7	21.5	4.4	5.1	4.3	9.1
Change, p.p.	-0.84	1.28	-0.99	-0.35	1.84	1.92	-1.78	0.89	-1.18	-0.79
Std. Dev.	0.51	0.48	0.77	0.44	1.00	1.24	0.65	0.40	0.56	0.89
Mean	4.44	16.25	5.67	11.94	17.22	22.03	4.98	4.79	4.04	8.65
CV	0.11	0.03	0.14	0.04	0.06	0.06	0.13	0.08	0.14	0.10

In economic research, HHI is a widely applied measure of specialisation. The normalised HHI (Al-Marhubi, 2000) can be used to measure the specialisation of regions in crop production. After dropping time index, we define the normalised HHI for the j-th region as follows:

$$HHI_j = \frac{\sqrt{\sum_{i=1}^{m}\left(\frac{a_{ij}}{A_j}\right)^2} - \sqrt{\frac{1}{m}}}{1-\sqrt{\frac{1}{m}}}, \tag{41}$$

where A_j is the total area sown for the j-th region, a_{ij} is the area sown under the i-th crop in the j-th region, m is the number of crops analysed. The index approaches zero (resp. unity) in case of low (resp. high) level of specialisation.

The trends in HHI for each county are presented in Fig. 2. As one can note, Lithuanian counties tended to diversify their crop-mixes during 2000-2010, whereas the opposite trend prevailed afterwards. As regards individual counties, Šiauliai and Marijampolė counties showed the highest degrees of the specialisation. On the contrary, counties abundant with low fertility lands appeared to be the least specialised ones (e.g. Vilnius and Alytus counties).

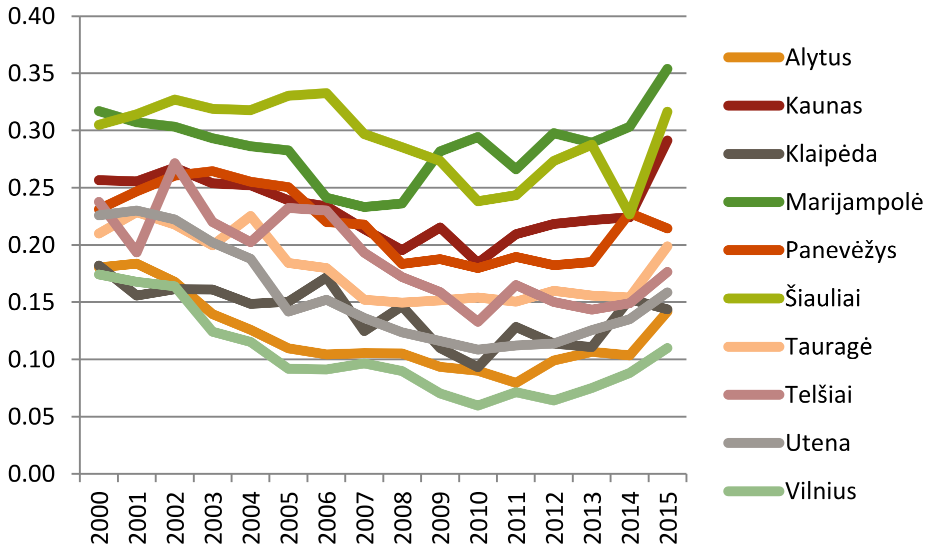


Fig. 2. Specialisation of counties (HHI), 2000-2015

Different support measures and changes in crop prices induce changes in areas sown under specific crops. Table 2 presents crop-specific trends in areas sown during 2000-2015. Spring barley was specific with the largest area sown exceeding 350 thousand ha, which accounted to some 30% of the national area sown in 2000. However it has declined by more than 40% until 2015. As a result the share of spring barley fell down to 12% in the national area sown. This can be explained by a decrease in animal population which resulted in lower demand for feedstuff. Winter wheat was the second most popular crop back in 2000 with area sown exceeding 285 thousand ha and accounting 24% of the national area sown. During 2000-2015, area sown under winter wheat increased twofold up to 573 thousand ha (34% of the national area sown). Therefore, winter wheat has become the most popular crop because of possibility for export into EU. Spring wheat occupied just 7% in the national area sown in 2000 (85 thousand ha). During the research period this share increased more than twice and reached 16% in 2015 (264 thousand ha). Therefore, spring wheat has become the second most popular crop in Lithuania.

Legumes are also specific with rather high rate of growth in area sown. Specifically, its area sown increased from 40 thousand ha up to 157 thousand ha during 2000-2015. The latter expansion can be attributed to increasing direct payment rates. Area sown under winter rape saw extremely high rate of growth as it went up from just 5 thousand ha up to 123 thousand ha. The demand for rape increased due to expansion for the biofuel production. As a result the share of legumes and winter rape in the national area sown increased for 4% up to 17%. The share of winter triticale in the national area sown increased by 3.1 p.p. and stood at 5.6% in 2015. As for other crops their shares in the national areas fell below 5% as of 2015.

Winter rye, spring rape and potatoes showed particularly steep decreases in their area sown. Indeed the latter crops used to be among the top ones in terms of area sown at the beginning of the research period and had turned into the least popular ones by 2015. Winter rye experienced the most evident decline in the share of national area sown of 8.9 p.p. (from 11.2% to 2.3%). This can be explained by lower prices compared to other cereals. Similarly, the share of national area sown for potatoes went down by 7.8 p.p. (from 9.2% to 1.4%). Indeed, the area sown under potatoes plummeted to 24 thousand ha. This is related to increased phytosanitary requirements against potato diseases. The contraction of the area sown under spring rape was not that significant as it decreased from 50 thousand ha to 41 thousand ha (i.e. from 4.2% down to 2.5% of the national area sown).

Crop-specific analysis indicated that crop-mix changed in Lithuania during 2000-2015 mostly due to policy and market factors. The accession to the EU made a more comprehensive agricultural support policy possible. In addition Lithuanian sectors became more integration into the common market. The effects of changes in crop-mix can also offset price fluctuation and smooth farm income. Therefore it is important to analyse the changes in crop revenue due country-wide changes in cropping patterns.

Assuming that producers within the country face the same prices, country-wide changes in crop-mix directly impact crop revenue due to price differences. Furthermore, crop movement across regions or changes in crop structure within regions alter the aggregate yields and, thus, crop revenue. The application of the IDA will enable to consider all of these factors simultaneously and isolate their impacts on crop revenue in Lithuania.

Table 2. The changes in the area sown across selected crops in Lithuania, 2000-2015

	Winter wheat	Winter triticale	Winter rye	Winter barley	Spring wheat	Spring barley	Spring triticale	Oats	Buckwheat	Mixed cereals	Maize	Legumes	Winter rape	Spring rape	Potatoes
	Area sown, ha														
2000	285549	29080	133060	1245	84931	351995	21655	44306	16601	11024	2913	39771	5360	50059	109331
2015	573314	93227	38229	3485	263773	199068	29197	64322	36819	17303	11965	157410	123485	41124	23573
Growth, %	100.8	220.6	-71.3	179.9	210.6	-43.4	34.8	45.2	121.8	57.0	310.7	295.8	2203.8	-17.8	-78.4
Std. Dev.	89450	27179	26213	5693	92508	62041	7341	9373	7588	5728	5795	31462	42389	55997	29368
Mean	339258	76435	64779	8388	138824	289841	17457	60823	25555	18492	7158	49839	56668	101855	59467
CV	0.26	0.36	0.40	0.68	0.67	0.21	0.42	0.15	0.30	0.31	0.81	0.63	0.75	0.55	0.49
	Share in the national area sown, %														
2000	24.1	2.5	11.2	0.1	7.2	29.7	1.8	3.7	1.4	0.9	0.2	3.4	0.5	4.2	9.2
2015	34.2	5.6	2.3	0.2	15.7	11.9	1.7	3.8	2.2	1.0	0.7	9.4	7.4	2.5	1.4
Change, p.p.	10.1	3.1	-8.9	0.1	8.6	-17.8	-0.1	0.1	0.8	0.1	0.5	6.0	6.9	-1.8	-7.8
Std. Dev.	3.8	1.6	2.5	0.4	5.3	7.3	0.4	0.4	0.4	0.4	0.3	1.7	2.7	3.7	2.9
Mean	25.6	5.7	5.2	0.6	9.9	23.0	1.3	4.6	1.9	1.4	0.5	3.6	4.0	7.6	4.9
CV	0.15	0.29	0.48	0.67	0.53	0.32	0.32	0.09	0.21	0.29	0.69	0.45	0.66	0.48	0.60

2.2. Crop yields

Generally, crop yields showed an upward trend in Lithuania during 2000-2015. In most cases, this can be explained by improved farming practises and increasing application agrochemicals (fertilisers, plant protection products). However, there is still a gap in yields in Lithuania and highly developed European countries. Table 3 summarises the trends in crop yields in Lithuania.

The highest increase in yield was observed for winter barley: it increased by 106% from 2.13 t/ha up to 4.39 t/ha throughout 2000-2015. However, the area sown under winter barley was relatively small and amounted to 1245 ha in 2000 and 3485 ha in 2015. Winter wheat, spring wheat, spring barley, maize, legumes and winter rape constituted the group of crops which saw and increase in yields of around 60%. The latter group of crops, indeed, occupied the largest share of the total area sown (see Table 2). Furthermore, this share (as well as absolute area) increased during the research period. Therefore, yield of these crops have been raised in spite of expansion to new areas, which might be specific with inferior farming conditions.

The yield of winter triticale grew by 47% from 2.77 t/ha in 2000 up to 4.07 t/ha in 2015. Spring triticale, oats, mixed cereals and spring rape showed yield growth rates ranging in between 32% and 38%. The share of these crops in the total area sown was rather small: they altogether occupied 10.6% of the total area sown in 2000 and this figure decreased to 9% in 2015. The lowest rate of yield growth was observed for potatoes. Indeed, the values 16.39 t/ha and 16.93 t/ha were observed for 2000 and 2015 respectively. The abundance of areas sown under these crops has decreased in Lithuania as they are associated with lower profitability and animal farming. Therefore farmers had fewer incentives to increase yields in remaining areas sown.

Notably, crop yields fluctuated due to climatic conditions. As regards the research period, major drops in crop yields were observed during 2006, 2010 and 2013. These periods can be considered as those defining the lowest observable yields and, thus, yield risk. Even though crop yields showed an upward trend in Lithuania during 2000-2015, assessment of agricultural risk is also related to inter-regional differences in crop yields. Indeed, convergence in crop yields among regions would indicate higher possibilities for diversification of crop-mix. Table 4, therefore, presents CVs for each crop during the research period. These CVs are based on county data. Accordingly, lower values of CVs indicate an increasing similarity of yields among counties. The linear trend was fitted to these values in order to represent the direction of change in CVs. In this case, negative values are associated with increase in yield convergence among regions (i.e., a certain CV tends to decrease over time). In most cases, the values of trend coefficient remained slightly negative indicating a slow convergence. Maize and winter rape appeared as the two crops with relatively high degree in yield convergence among regions. Therefore, even though crop yields has increased in Lithuania, regional differences have also persisted.

Table 3. The changes in crop yields in Lithuania, 2000-2015

	Winter wheat	Winter triticale	Winter rye	Winter barley	Spring wheat	Spring barley	Spring triticale	Oats	Buckwheat	Mixed cereals	Maize	Legumes	Winter rape	Spring rape	Potatoes
2000	3.56	2.77	2.34	2.13	2.62	2.43	2.32	1.87	0.89	1.79	2.85	1.84	2.22	1.38	16.39
2001	3.17	2.52	2.08	2.64	2.59	2.31	2.03	1.76	0.75	1.78	2.85	1.42	1.83	1.10	10.28
2002	3.84	2.82	2.28	3.02	2.82	2.37	1.99	1.77	0.62	1.49	2.85	1.74	2.09	1.58	15.44
2003	3.61	2.75	2.46	2.67	3.40	2.93	2.64	2.38	0.90	2.00	3.17	2.24	1.72	1.80	15.44
2004	4.12	3.18	2.54	3.78	3.45	2.93	2.72	2.23	0.59	2.08	2.20	1.88	2.70	1.82	12.88
2005	3.85	2.73	2.12	3.24	3.24	2.70	2.33	1.92	0.55	1.83	3.08	1.64	2.51	1.60	12.10
2006	2.46	1.73	1.76	2.32	2.08	1.93	1.42	1.06	0.28	1.02	2.36	0.81	1.73	0.99	7.91
2007	4.16	2.95	2.37	3.15	3.08	2.64	2.17	1.94	0.96	1.92	4.82	1.39	2.09	1.60	10.91
2008	4.76	3.27	2.76	3.94	3.01	2.88	2.33	2.07	0.76	1.91	4.25	1.70	2.72	1.58	14.79
2009	4.40	3.17	2.53	3.83	3.41	3.03	2.73	2.23	0.67	2.01	4.33	1.80	2.53	1.71	14.23
2010	3.35	2.37	1.68	2.40	3.02	2.28	2.06	1.51	0.70	1.54	6.62	1.28	1.93	1.45	12.69
2011	3.26	2.48	1.98	2.82	3.46	2.99	2.37	2.01	0.95	1.96	7.47	1.68	1.75	1.93	15.40
2012	5.17	3.80	2.80	4.42	3.87	3.36	2.90	2.27	0.83	2.16	5.65	1.83	3.38	1.99	16.96
2013	4.55	3.17	1.95	3.58	3.70	3.25	2.88	2.23	0.92	2.25	7.15	2.00	2.47	1.81	14.73
2014	4.76	3.30	2.25	4.11	4.31	3.80	3.11	2.41	0.94	2.55	6.00	2.45	2.72	1.94	17.13
2015	5.71	4.07	2.79	4.39	4.20	4.00	3.06	2.54	0.99	2.43	4.71	2.89	3.51	1.91	16.93
Growth, %	60.5	46.6	19.2	106.4	60.6	64.3	32.0	35.8	11.6	35.6	65.2	57.2	58.0	38.3	3.3
Std. Dev.	0.8	0.6	0.3	0.7	0.6	0.6	0.5	0.4	0.2	0.4	1.7	0.5	0.6	0.3	2.7
Mean	4.0	2.9	2.3	3.3	3.3	2.9	2.4	2.0	0.8	1.9	4.4	1.8	2.4	1.6	14.0
CV	0.21	0.19	0.15	0.23	0.18	0.19	0.19	0.19	0.25	0.19	0.40	0.27	0.23	0.18	0.19

Table 4. Regional convergence in crop yields as represented by CV in Lithuania, 2000-2015

	Winter wheat	**Winter triticale**	**Winter rye**	**Winter barley**	**Spring wheat**	**Spring barley**	**Spring triticale**	**Oats**	**Buckwheat**	**Mixed cereals**	**Maize**	**Legumes**	**Winter rape**	**Spring rape**	**Potatoes**
2000	0.24	0.23	0.19	0.31	0.18	0.22	0.23	0.21	0.20	0.27	0.67	0.31	0.32	0.22	0.16
2001	0.15	0.23	0.13	0.30	0.17	0.16	0.15	0.15	0.26	0.27	0.67	0.14	0.37	0.23	0.17
2002	0.20	0.23	0.17	0.29	0.26	0.21	0.15	0.16	0.35	0.28	0.67	0.25	0.20	0.12	0.12
2003	0.19	0.14	0.16	0.21	0.22	0.22	0.13	0.17	0.28	0.19	0.51	0.23	0.14	0.15	0.14
2004	0.18	0.16	0.15	0.24	0.19	0.14	0.20	0.12	0.36	0.16	0.52	0.13	0.27	0.14	0.23
2005	0.22	0.21	0.17	0.36	0.26	0.20	0.20	0.16	0.26	0.12	0.63	0.20	0.31	0.20	0.15
2006	0.26	0.27	0.20	0.37	0.25	0.26	0.25	0.22	0.41	0.31	0.58	0.38	0.47	0.36	0.23
2007	0.20	0.15	0.15	0.22	0.21	0.18	0.19	0.13	0.30	0.14	0.40	0.26	0.28	0.16	0.17
2008	0.22	0.19	0.13	0.35	0.20	0.21	0.24	0.14	0.13	0.22	0.45	0.20	0.27	0.22	0.19
2009	0.19	0.15	0.16	0.19	0.18	0.18	0.25	0.16	0.29	0.17	0.31	0.23	0.25	0.13	0.23
2010	0.23	0.27	0.17	0.38	0.26	0.23	0.28	0.20	0.23	0.25	0.22	0.30	0.30	0.16	0.22
2011	0.22	0.25	0.24	0.25	0.21	0.19	0.18	0.14	0.11	0.21	0.13	0.28	0.27	0.13	0.19
2012	0.19	0.23	0.18	0.26	0.22	0.18	0.19	0.17	0.14	0.18	0.11	0.24	0.23	0.11	0.18
2013	0.19	0.25	0.15	0.21	0.16	0.18	0.28	0.16	0.16	0.25	0.21	0.23	0.22	0.13	0.16
2014	0.25	0.25	0.13	0.18	0.20	0.16	0.22	0.16	0.55	0.17	0.23	0.20	0.22	0.14	0.13
2015	0.14	0.17	0.18	0.22	0.16	0.16	0.21	0.13	0.15	0.16	0.21	0.21	0.09	0.09	0.17
Trend	**-0.0003**	**0.0016**	**0.0004**	**-0.0054**	**-0.0017**	**-0.0019**	**0.0044**	**-0.0013**	**-0.0040**	**-0.0037**	**-0.0397**	**0.0004**	**-0.0076**	**-0.0061**	**0.0008**

2.3. Aggregate advantage index

AAI comprises scale advantage index and comparative advantage index (cf. Section 1.2). Specifically, scale advantage index measures the relative importance of a region in production of a certain crop, whereas comparative advantage index compares yields across the regions (i.e., reciprocals of land requirements per unit of production). Therefore, values of AAI greater than unity indicates specialisation of a certain region in production of a crop. AAI along with its components was calculated for each crop, region, and year. For sake of brevity, Table 5 presents geometric averages for the whole research period. In order to present the underlying dynamics in AAI, linear trend coefficients are also given for each county.

In accordance with the AAI, the three counties, viz., those of Kaunas, Marijampolė, and Šiauliai, showed specialisation in the production of winter wheat. The county of Panevėžys showed the mean value of AAI equal to 0.98 thus indicating rather small distance from the specialised counties. Tough, a more detailed analysis showed that the latter county maintained relatively larger areas of winter wheat (scale advantage), yet most of the periods marked relatively lower yields (comparative advantage). Therefore, the area sown under winter wheat could be reduced in that county. The highest mean value of AAI was observed for Marijampolė county (1.28), whereas Kaunas and Šiauliai counties exhibited the values of 1.11 and 1.14 respectively. Indeed, the latter county showed a negative trend coefficient indicating that the degree of advantage was decreasing there. As regards winter triticale, Tauragė and Telšiai appeared as two counties with highest values of AAI, namely 1.31 and 1.22, respectively. In both cases, the higher values of AAI were determined by scale advantage rather than comparative advantage. Klaipėda county followed in the order of AAI with the value of 1.15. Noteworthy, the counties of Tauragė and Klaipėda showed the lowest coefficients of the linear trend thus indicating decreasing level of advantage. The counties of Panevėžys, Šiauliai, Vilnius, and Utena were those showing no specialisation in the production of winter triticale (the corresponding AAIs ranged in between 0.8 and 0.88). Vilnius county showed the highest mean advantage (1.55) in winter rye production, whereas the counties of Alytus and Utena (AAIs of 1.33 and 1.29, respectively). Specifically, these aggregate advantages were mainly rendered by scale advantage. All of these counties exhibited positive trends in AAIs. Šiauliai and Marijampolė counties were attributed with the lowest values of AAI, namely 0.6 and 0.56, respectively. Furthermore, these counties followed downward trends in aggregate advantage. Three counties, namely Kaunas, Šiauliai, and Marijampolė, showed aggregate advantage in winter barley production. Specifically, the former two counties were specific with rather similar values of 1.12 and 1.19, respectively, whereas the latter one exhibited the value of just 1.03. The lowest value of AAI was observed for Klaipėda county (0.46). Indeed, this county was specific with the steepest negative trend. A deeper analysis indicates that Kaunas, Šiauliai, and Marijampolė counties experienced comparative advantage. Furthermore, Kaunas and Šiauliai counties experienced scale advantage.

Table 5. AAI across crops and counties in Lithuania, 2000-2015

	Winter wheat	Winter triticale	Winter rye	Winter barley	Spring wheat	Spring barley	Spring triticale	Oats	Buckwheat	Mixed cereals	Maize	Legumes	Winter rape	Spring rape	Potatoes
	AAI														
Alytus	0.73	1.10	1.33	0.69	0.72	0.77	1.09	1.57	1.71	1.39	0.92	0.90	0.57	0.49	1.35
Kaunas	1.11	1.09	0.97	1.12	1.05	0.98	0.90	0.85	0.62	0.86	1.06	0.93	1.02	1.09	0.94
Klaipėda	0.48	1.15	1.02	0.46	1.05	0.91	1.49	1.53	0.64	1.26	0.56	1.06	0.63	0.78	1.35
Marijampolė	1.28	1.09	0.56	1.03	1.23	0.90	0.71	0.75	0.35	1.00	1.63	0.85	0.99	1.09	0.96
Panevėžys	0.98	0.83	1.09	0.77	1.05	1.04	1.08	0.67	1.13	0.80	0.93	1.08	0.90	1.13	0.81
Šiauliai	1.14	0.80	0.60	1.19	0.90	1.20	0.79	0.62	0.32	0.61	0.73	0.93	1.36	1.10	0.75
Tauragė	0.89	1.31	0.95	0.57	0.96	0.92	1.13	1.11	0.40	1.33	0.79	0.99	0.65	0.75	1.23
Telšiai	0.68	1.22	1.01	0.79	0.74	1.04	0.86	1.53	0.35	1.40	0.52	1.18	0.60	0.65	1.07
Utena	0.65	0.81	1.29	0.51	0.84	0.80	1.05	1.11	1.56	1.04	0.61	0.82	0.33	0.77	1.23
Vilnius	0.51	0.88	1.55	0.68	0.81	0.67	1.08	1.45	2.10	1.20	0.60	1.16	0.43	0.53	1.22
	Trend for AAI														
Alytus	0.012	0.002	0.023	-0.004	-0.014	-0.015	-0.007	0.025	-0.008	-0.012	0.015	-0.007	0.004	0.018	0.009
Kaunas	0.005	0.001	-0.014	-0.011	0.013	-0.009	-0.018	-0.008	-0.017	-0.013	-0.024	0.001	0.012	0.008	-0.002
Klaipėda	-0.004	-0.018	-0.007	-0.043	0.000	0.015	0.070	0.007	0.025	-0.004	0.027	0.022	-0.058	0.014	0.009
Marijampolė	0.009	-0.003	-0.019	-0.012	-0.015	-0.030	0.000	-0.007	-0.016	0.003	-0.016	-0.017	-0.003	0.006	0.007
Panevėžys	-0.021	-0.002	0.006	0.017	0.004	0.003	-0.011	0.008	0.029	0.002	0.004	0.006	-0.021	-0.005	0.000
Šiauliai	-0.007	0.012	-0.016	0.010	-0.011	0.010	-0.007	-0.001	-0.015	0.001	0.012	-0.016	0.007	-0.030	-0.002
Tauragė	0.003	-0.018	0.010	-0.008	-0.006	0.005	0.021	0.007	-0.010	0.049	0.043	0.016	-0.013	0.030	0.003
Telšiai	0.009	-0.001	0.005	-0.021	0.001	0.016	0.021	-0.008	-0.016	-0.012	-0.004	0.008	0.001	-0.005	-0.005
Utena	0.011	0.018	0.016	-0.022	0.023	-0.005	0.007	0.013	0.014	0.010	-0.017	0.018	0.006	0.033	0.008
Vilnius	0.011	0.008	0.020	0.019	0.015	-0.006	-0.011	0.001	-0.004	0.018	0.039	0.007	0.024	0.029	-0.003

The mean AAI for spring wheat production ranged in between 0.72 and 1.23 across Lithuanian counties. The highest value was observed for Marijampolė county. Kaunas, Klaipėda and Panevėžys counties we also specific with aggregate advantage (1.05). Out of these counties, Kaunas county showed a positive trend, Marijampolė county – a negative one. Klaipėda and Panevėžys counties followed a flat trend, i.e. trend coefficients were closed to zero. All the enumerated counties experienced scale advantage in spring wheat production. With exception of Klaipėda county, these counties also enjoyed comparative advantage.

The mean AAI for spring barley production exceeded the value of unity for three counties. Šiauliai county featured the highest value of AAI (1.2). Panevėžys and Telšiai counties stood at much lower values of 1.04. Šiauliai and Telšiai counties showed a positive trend in AAI, whereas Panevėžys county followed a rather flat one. All the three counties showed scale advantage, yet only Panevėžys and Šiauliai counties experienced comparative advantage.

The highest mean AAI for spring triticale was observed for Klaipėda county (1.49). The latter value was determined by scale advantage. Indeed, this county showed the positive trend in AAI. Alytus, Panevėžys, Tauragė, Utena and Vilnius counties showed also showed aggregate advantage in spring triticale production as the mean AAI ranged in between 1.05 and 1.13 here. While scale effect was present in each of these counties, comparative advantage was observed in Panevėžys and Tauragė counties only.

Oat production was related to a rather wide range of the values of the mean AAI. The minimal value of 0.62 was observed for the Šiauliai county, whereas the maximal value of 1.57 was observed for the Alytus county. Alytus, Klaipėda and Telšiai counties were specific with AAI values exceeding 1.5. The latter counties experienced scale advantages. In addition, Telšiai county experienced comparative advantage. Tauragė and Utena counties also featured aggregate advantage, however the value of AAI equalled to 1.11. The steepest positive trends in AAI were observed for Alytus and Utena counties.

The highest values of AAI for buckwheat production were observed for Vilnius and Alytus counties (2.1 and 1.71 respectively). Both of these counties relied on scale advantage, whereas comparative advantage was observed for Vilnius county during certain sub-periods. Utena and Panevėžys counties showed AAIs of 1.56 and 1.13 respectively. The lowest values of AAI were observed for Marijampolė, Šiauliai and Telšiai counties (0.32-0.35). Given the estimated trend coefficients the highest rates of growth were observed for Klaipėda and Panevėžys counties.

Focusing on mixed cereal production, only the counties Kaunas, Panevėžys and Šiauliai showed no aggregate advantages. Marijampolė county showed the AAI of unity due to comparative advantage. Utena county showed the value of 1.04. The remaining counties exhibited the values of AAI falling within the range bounded by 1.2 and 1.4. With exception of Tauragė county, these values were influenced by scale advantage.

The maximum slopes for trends in AAI were estimated for Tauragė and Vilnius counties.

Marijampolė county had the highest aggregate advantage in maize production (1.63) due to both comparative and scale advantage. Kaunas county showed much lower degree of aggregate advantage (1.06) which was mainly due to comparative advantage. Both of these counties showed negative coefficients of the trend of AAI. Alytus and Panevėžys counties showed the values of AAI equal to 0.92 and 0.93, respectively. The remaining counties exhibited much lower values of AAI bounded by 0.52 and 0.79. Tauragė and Vilnius counties showed the highest coefficients for the trend.

The values of AAI for legume production were rather even across counties with the minimum value of 0.82 for Utena county and the maximum one of 1.18 for Telšiai county. Telšiai and Vilnius counties showed the highest values of AAI (1.18 and 1.16) respectively. Klaipėda and Panevėžys counties featured lower aggregate advantage (1.06 and 1.08) respectively. Klaipėda county showed the highest coefficient of trend. The four counties specific with the aggregate advantage experienced both comparative and scale advantages (Vilnius county experienced scale advantage only).

Only two counties, namely Šiauliai and Kaunas, exhibited aggregate advantage in winter rape production. This advantage was caused by both comparative and scale advantages. The degree of aggregate advantage was much lower in Kaunas county (1.02) if compared to Šiauliai county (1.36). However, the trend coefficient was higher for Kaunas county. Utena and Vilnius counties appeared as the least advantageous ones (AAIs of 0.33 and 0.43 respectively).

As regards spring rape production four counties had aggregate advantage, namely Kaunas, Marijampolė, Panevėžys and Šiauliai counties. These counties were rather similar in the degrees of aggregate advantage as there mean AAIs ranged in between 1.09 and 1.13. All of these counties experienced scale advantages, whereas comparative advantage was observed for Kaunas, Marijampolė and Šiauliai counties. The latter county followed a strongly negative trend in AAI.

Alytus and Klaipėda counties showed the highest means in AAIs of 1.35 for potato production. In both cases positive trend was observed. Tauragė, Utena and Vilnius were also specific with similar levels of AAI (1.22-1.23). Telšiai county featured AAI of 1.07. All of the aforementioned counties experienced scale advantage, yet comparative advantage was identified for Klaipėda and Tauragė counties only. The lowest mean AAI was observed for Šiauliai county (0.75).

The analysis indicated that different counties experienced aggregate advantage in production of different crops. In many instances, scale and comparative advantages were observed for different counties. Furthermore, the differences in trends for AAIs indicated the dynamics of disparities in crops structures and yields.

2.4. Dynamics in crop revenue

The revenue for the crops analysed is approximated in terms of harvests and prices as provided by Statistics Lithuania (2016). The total revenue amounted to some 441 million EUR in 2000 and went up to 1 254 million EUR in 2015. The dynamics in the total revenue are depicted in Fig. 3. Obviously, the research period can be divided into two sub-periods differing in terms of growth rates in crop revenue. First, the period of 2000-2006 marks a rather steady level of crop revenue with a slight decrease in 2006 due to unfavourable weather. Specifically, the most significant change in crop revenue was that of 2005-2006, when a decline of some 15% was observed. In the previous years, the rates of change ranged in between -6% and 3%. Second, the period of 2006-2015 features more stochastic crop revenue. The rates of growth in the total crop revenue for the latter period fell within the range of -31% and 78%. These changes were mainly fuelled by support payments under Common Agricultural Policy and integration into the European market. These results stress the need for sub-period analysis of factors underlying the changes in crop revenue. Indeed, the IDA methodology is capable to handle such problems.

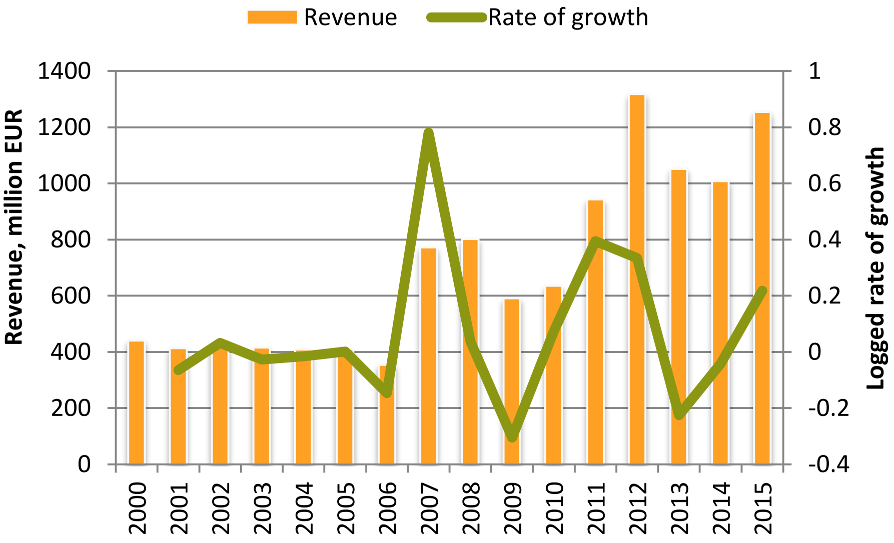


Fig. 3. Total crop revenue in Lithuania, 2000-2015

The changes in crop revenue can also be analysed in a crop-wise manner in order to describe the dynamics in preferences of farmers and the resulting shifts in crop structure. Table 6 presents both absolute and relative measures of crop revenue for different crops. As one can note, some crops accounted for a rather high share of revenue throughout the research period (e.g., winter wheat), while others saw a decreasing share in the total revenue (e.g., spring barley and potatoes). These changes can be governed by multiple factors including consumer preferences, changes in prices and yields, among others.

Looking at absolute figures on crop revenue, one can notice only few crops that experienced decreasing revenue during 2000-2015. More specifically, revenue for winter rye decreased by 2.4% p.a. on average (from 29.6 million EUR in 2000 down to 12.2 million EUR in 2015). Potatoes appeared as another crop facing decreasing revenue with average annual rate of decrease equalling 4.2%. In the latter case, revenue plummeted from 118.2 million EUR down to 52.3 million EUR during 2000-2015. At the other end of spectrum, winter rape, maize, and spring wheat showed the highest average annual rates of growth for the associated revenue. Such changes could be the outcomes of changes in both intensive and extensive developments (e.g., increasing areas sown and selling prices).

Table 6. The changes in crop revenue across different crops, 2000-2015

Crop	Revenue, million EUR				Structure of revenue, %			
	2000	2007	2015	Annual rate of growth, %	2000	2007	2015	Rate of change, p.p.
Winter wheat	121.8	213.0	523.5	9.9	27.6	27.6	41.7	14.1
Winter triticale	8.2	30.9	47.0	12.6	1.9	4.0	3.7	1.9
Winter rye	29.6	25.3	12.2	-2.4	6.7	3.3	1.0	-5.7
Winter barley	0.3	7.0	2.2	10.8	0.1	0.9	0.2	0.1
Spring wheat	26.7	44.3	177.4	18.0	6.0	5.7	14.1	8.1
Spring barley	94.3	179.6	114.7	2.6	21.4	23.2	9.1	-12.2
Spring triticale	5.1	4.4	11.1	10.7	1.2	0.6	0.9	-0.3
Oats	5.8	17.7	19.8	8.2	1.3	2.3	1.6	0.3
Buckwheat	3.5	5.5	15.2	12.3	0.8	0.7	1.2	0.4
Mixed cereals	1.4	7.8	5.1	9.7	0.3	1.0	0.4	0.1
Maize	1.0	4.7	8.1	24.8	0.2	0.6	0.6	0.4
Legumes	10.2	8.6	91.4	12.7	2.3	1.1	7.3	5.0
Winter rape	2.2	39.1	147.9	25.9	0.5	5.1	11.8	11.3
Spring rape	12.7	46.9	26.8	14.2	2.9	6.1	2.1	-0.7
Potatoes	118.2	137.7	52.3	-4.2	26.8	17.8	4.2	-22.6
Total	**441.0**	**772.5**	**1254.4**					

Notes: (i) annual rate of growth for revenue is based on log-linear regression; (ii) rate of change for shares in revenue is measured for 2000 and 2015.

The two crops featuring decrease in revenue during 2000-2015 also showed decrease in the share of the total crop revenue. As for potatoes, its share shrunk from 26.8% down to 4.2% during 2000-2015. The share of winter rye dropped from 6.7% down to 1% during the same period. In addition, some other crops also showed a decreasing relative importance in terms of revenue. For instance, spring barley saw a decrease of 12.2 p.p. in the total revenue. Such cases illustrate the complexity of dynamics in the total crop revenue arising from interactions of multiple factors that might have different impact across different crops. Therefore, it is important to analyse the factors behind changes in crop revenue in terms of multiple dimensions.

3. APPRAISAL OF PRODUCTION RISK

This section presents the estimates of production risk based on analysis of yield variation. First, the yield series are smoothed by means of LMA. Second, we show the differences between conventional measures of standard deviation and downside ones. Insurance premiums along with the other measures of production risk are estimated with respect to statistical distributions. Finally, the obtained risk measures are related to AAI in order to identify the most problematic regions and crops.

This section focuses on yield risk as a main component of the production risk. Indeed, this type of risk can be managed by means of insurance and policy measures. The price risk is not considered in this section as it is related to global markets and tightly regulated by income support measures.

3.1. Deviations from yield trends

The trends for yields (and prices) were estimated by means of LMA. With increasing step size k, the trend approaches linear one and squared error increases. On the contrary, smaller values of step size imply higher variance and mask the general trend. Therefore, it is important to pick the proper step size. Initially, different sizes of steps (timespans) were applied in order to choose the minimum value ensuring smooth trend. In our case, the value of six years was chosen as the step size for LMA. The following Fig. 4 presents the LMA trend for winter wheat yield in Alytus county. As one can note, the trend had no positive slope until year 2006 and became exponential later on.

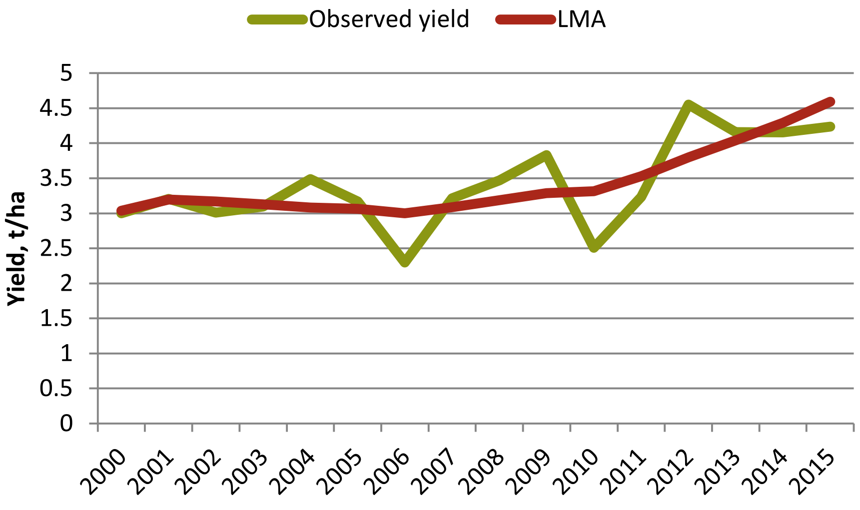


Fig. 4. The yield of winter wheat in Alytus county, 2000-2015

The estimated trends can be used for computation of DCV, production risk etc. For sake of completeness, we also compute a conventional measure of variation, namely CV. Table 7 presents the results on yield variation for different crops and counties. In order to demonstrate the implications of the use of different measures, counties are ranked with respect to these.

Table 7. Yield variation across counties and crops (CV and DCV), 2000-2015

	Alytus	**Kaunas**	**Klaipėda**	**Marijampolė**	**Panevėžys**	**Šiauliai**	**Tauragė**	**Telšiai**	**Utena**	**Vilnius**
	Winter wheat									
CV	0.18	0.22	0.26	0.19	0.22	0.22	0.22	0.24	0.25	0.26
DCV	0.09	0.10	0.15	0.09	0.13	0.11	0.10	0.11	0.12	0.12
Rank (CV)	10	5	1	9	6	7	8	4	3	2
Rank (DCV)	10	7	1	9	2	5	8	6	3	4
	Winter triticale									
CV	0.16	0.20	0.26	0.21	0.23	0.23	0.21	0.20	0.26	0.22
DCV	0.09	0.09	0.14	0.11	0.13	0.12	0.11	0.10	0.15	0.12
Rank (CV)	10	9	1	6	4	3	7	8	2	5
Rank (DCV)	10	9	2	7	3	5	6	8	1	4
	Winter rye									
CV	0.18	0.18	0.22	0.16	0.17	0.20	0.17	0.09	0.19	0.16
DCV	0.10	0.09	0.12	0.08	0.10	0.11	0.11	0.05	0.10	0.10
Rank (CV)	4	5	1	8	7	2	6	10	3	9
Rank (DCV)	5	8	1	9	4	2	3	10	7	6
	Winter barley									
CV	0.31	0.25	0.45	0.22	0.31	0.18	0.32	0.38	0.44	0.34
DCV	0.18	0.12	0.16	0.12	0.17	0.08	0.13	0.12	0.22	0.14
Rank (CV)	6	8	1	9	7	10	5	3	2	4
Rank (DCV)	2	9	4	7	3	10	6	8	1	5
	Spring wheat									
CV	0.20	0.22	0.25	0.16	0.19	0.19	0.19	0.23	0.25	0.19
DCV	0.10	0.08	0.09	0.06	0.09	0.09	0.06	0.09	0.09	0.08
Rank (CV)	5	4	2	10	9	7	8	3	1	6
Rank (DCV)	1	8	5	9	3	4	10	2	6	7
	Spring barley									
CV	0.20	0.22	0.25	0.16	0.19	0.19	0.21	0.21	0.29	0.24
DCV	0.12	0.07	0.07	0.06	0.09	0.07	0.08	0.06	0.12	0.10
Rank (CV)	7	4	2	10	8	9	5	6	1	3
Rank (DCV)	2	7	8	9	4	6	5	10	1	3
	Spring triticale									
CV	0.35	0.25	0.22	0.21	0.19	0.24	0.19	0.18	0.24	0.23
DCV	0.16	0.09	0.10	0.09	0.10	0.11	0.09	0.09	0.14	0.11
Rank (CV)	1	2	6	7	9	3	8	10	4	5
Rank (DCV)	1	10	5	9	6	3	8	7	2	4

Table 7 continued

	Alytus	Kaunas	Klaipėda	Marijampolė	Panevėžys	Šiauliai	Tauragė	Telšiai	Utena	Vilnius
	Oats									
CV	0.19	0.18	0.19	0.20	0.19	0.20	0.23	0.20	0.23	0.22
DCV	0.11	0.11	0.10	0.12	0.12	0.11	0.10	0.12	0.12	0.13
Rank (CV)	9	10	8	6	7	5	2	4	1	3
Rank (DCV)	6	8	10	4	3	7	9	5	2	1
	Buckwheat									
CV	0.25	0.26	0.32	0.32	0.28	0.60	0.28	0.35	0.34	0.27
DCV	0.14	0.15	0.17	0.13	0.14	0.28	0.15	0.19	0.14	0.12
Rank (CV)	10	9	5	4	7	1	6	2	3	8
Rank (DCV)	7	5	3	9	8	1	4	2	6	10
	Mixed cereals									
CV	0.21	0.25	0.26	0.18	0.25	0.26	0.28	0.19	0.29	0.23
DCV	0.14	0.13	0.14	0.09	0.14	0.13	0.11	0.09	0.12	0.13
Rank (CV)	8	5	4	10	6	3	2	9	1	7
Rank (DCV)	3	5	2	9	1	6	8	10	7	4
	Maize									
CV	0.33	0.33	0.74	0.33	0.56	0.57	0.45	0.82	0.79	0.70
DCV	0.13	0.11	0.21	0.09	0.19	0.18	0.20	0.19	0.34	0.20
Rank (CV)	9	10	3	8	6	5	7	1	2	4
Rank (DCV)	8	9	2	10	5	7	4	6	1	3
	Legumes									
CV	0.29	0.25	0.27	0.29	0.27	0.25	0.26	0.25	0.32	0.34
DCV	0.14	0.09	0.12	0.10	0.13	0.11	0.06	0.11	0.13	0.13
Rank (CV)	4	9	6	3	5	10	7	8	2	1
Rank (DCV)	1	9	5	8	3	7	10	6	2	4
	Winter rape									
CV	0.27	0.25	0.37	0.26	0.32	0.23	0.33	0.34	0.44	0.36
DCV	0.17	0.12	0.16	0.14	0.17	0.11	0.15	0.14	0.37	0.14
Rank (CV)	7	9	2	8	6	10	5	4	1	3
Rank (DCV)	2	9	4	6	3	10	5	7	1	8
	Spring rape									
CV	0.19	0.17	0.27	0.15	0.25	0.19	0.23	0.18	0.26	0.29
DCV	0.11	0.10	0.13	0.07	0.13	0.11	0.07	0.12	0.16	0.10
Rank (CV)	6	9	2	10	4	7	5	8	3	1
Rank (DCV)	5	8	3	10	2	6	9	4	1	7
	Potatoes									
CV	0.24	0.20	0.25	0.20	0.20	0.22	0.26	0.22	0.25	0.21
DCV	0.14	0.10	0.13	0.10	0.09	0.16	0.13	0.11	0.11	0.09
Rank (CV)	4	9	3	10	8	5	1	6	2	7
Rank (DCV)	2	7	3	8	10	1	4	6	5	9

Note: the rounded values are provided for CVs and DCVs.

The ranks of coefficients for different counties might differ across CV and DCV due to the two reasons. First, the squared error might be reduced by considering negative distances from observed values to fitted ones only. Second, the extent of these alterations might vary across counties. Fig. 5 presents the coefficients of correlation for ranks of the resulting CVs and DCVs. These data can provide information on the effect of inclusion of the time trend and DCV into analysis.

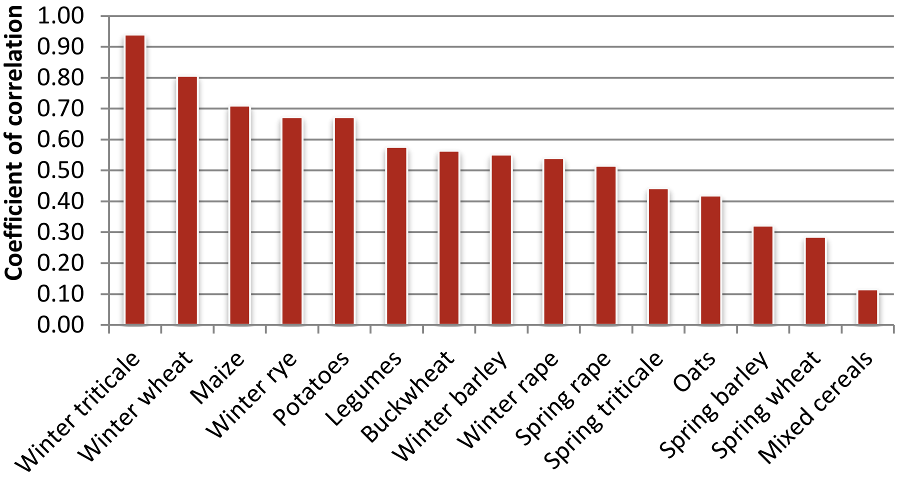


Fig. 5. Correlation of ranks of CVs and DCVs for yields of different crops

The data in Fig. 5 indicate the existing differences in ranking of counties according to the two coefficients of variation. The highest differences are observed for mixed cereals, spring wheats, spring barley, oats and spring triticale (coefficients of correlation do not exceed the value of 0.44). For winter triticale and winter wheat, the highest values the coefficients of correlation are observed (over 0.8). The variation in yields of latter crops, therefore, shows the same pattern across CV and DCV.

Lower values of CV and DCV indicate regions with relatively stable trends in yields. The highest variation in winter wheat yields was observed in Klaipėda county. Kaunas, Tauragė, Marijampolė and Alytus counties showed the lowest variation in yields as suggested by DCV. Focusing on winter triticale, Alytus, Kaunas and Telšiai counties featured the lowest variation in yields. Note, that results for winter triticale are highly consistent across CV and DCV. The lowest values of DCV for winter rye were observed in Telšiai and Marijampolė counties. As for winter barley Šiauliai and Kaunas counties showed the lowest values of DCV. Tauragė and Marijampolė counties exhibited the lowest value of DCV for spring wheat. However, the difference between the minimum DCV (0.06) and maximum DCV (0.1) was rather marginal one. Marijampolė and Telšiai appeared to have the lowest DCVs for spring barley. As regards spring triticale, Kaunas and Marijampolė counties featured the lowest values of DCV. The analysed counties were rather similar in terms of oat yield variation as DCVs ranged in between 0.1 for Klaipėda county and 0.1 for Vilnius county. Vilnius and Marijampolė counties appeared as those specific with the lowest values of DCV for buckwheat. The lowest values of DCV for mixed cereals were observed for Telšiai and Marijampolė counties. Turning to maize, Marijampolė and Kaunas counties showed the lowest variation in yields, as suggested by DCV. Tauragė and Kaunas counties emerged as the regions specific with the lowest values of DCV for legumes. The lowest variation in winter rape yields was observed in Šiauliai and Kaunas counties. As for spring rape the lowest values of DCV were observed for Marijampolė and Tauragė counties. Finally, Panevėžys and Vilnius counties featured the lowest values of DCV for potatoes. All in all, the lowest values of DCV were observed in rather exceptional cases for Vilnius, Utena and Klaipėda counties. This suggests these counties are specific with the most uncertain climatic conditions and crop yields.

Even though CV and DCV can provide some information about distribution of yields, additional approaches might be taken in order to derive probability-based measures. For instance, the probabilities of decrease in yields (of different degrees) can complement the analysis. Furthermore, CV and DCV are based on empirical data and do not allow for inference of critical events. Finally, low values of CV and DCV might be observed for negative trends. Therefore, statistical distributions can be fitted to yield data in order to model production risk.

3.2. Estimates of production risk

Yield loss ratios (Eq. 13) were estimated by employing the observed data and LMA trend (see Section 3.1). Thereafter, the data for each crop and county were used to estimate density functions of normal and logistic distributions as described in Section 1.3.

The estimated density functions were then integrated in order to measure the production risk across crops and counties. Following Zhang and Wang (2010), we consider the three measures: probability of loss, risks of hazards of different degrees, and mean hazard. Fig. 6 presents a graphical interpretation of these measures (variable y represents yields loss ratio).

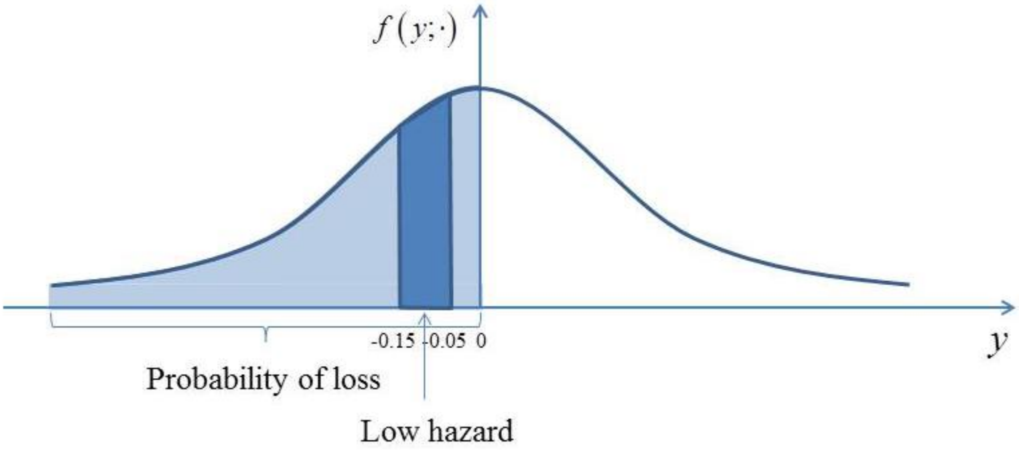


Fig. 6. The measures of production risk

First, probability of loss is measured as the area under the density curve to the left of zero point (light-shaded area in Fig. 6). However, small deviations from the trend might not induce serious losses and, therefore, can be ignored. Accordingly, the density function can be integrated over certain range of yield loss ratio (or any other variable of interest) thus defining the second type of risk measures. For instance, the dark-shaded area in Fig. 6 corresponds to probability of low hazard, i.e. yield loss ratio of -0.15 to -0.05. Liu et al. (2006) defined the four degrees of hazard (low, medium, high, catastrophic) with corresponding ranges of the yield loss ratio. Having calculated probabilities for each of different levels of hazard, one can aggregate these by means of weighted average. This renders the third measure of risk, namely, mean hazard. Following Zhang and Wang (2010), we define the mean hazard as:

$$\begin{aligned}\text{mean hazard} = {} & \Pr(\text{low hazard})\cdot 10\% + \Pr(\text{medium hazard})\cdot 20\% \\ & + \Pr(\text{high hazard})\cdot 30\% + \Pr(\text{catastrophic hazard})\cdot 40\% \end{aligned}. \quad (42)$$

The third measure ignores the smallest deviations from the trend and limits the magnitude of extreme events.

Fig. 7 and 8 present the average probabilities of yield loss for crops analysed. Results in the former picture are based on the normal distribution, whereas those in the latter one – on the logistic distribution. By comparing these two figures, one can note the differences in probabilities of yield loss due to application of different statistical distributions. The inverse of a probability can be interpreted as a number of years between two subsequent occurrences of an event.

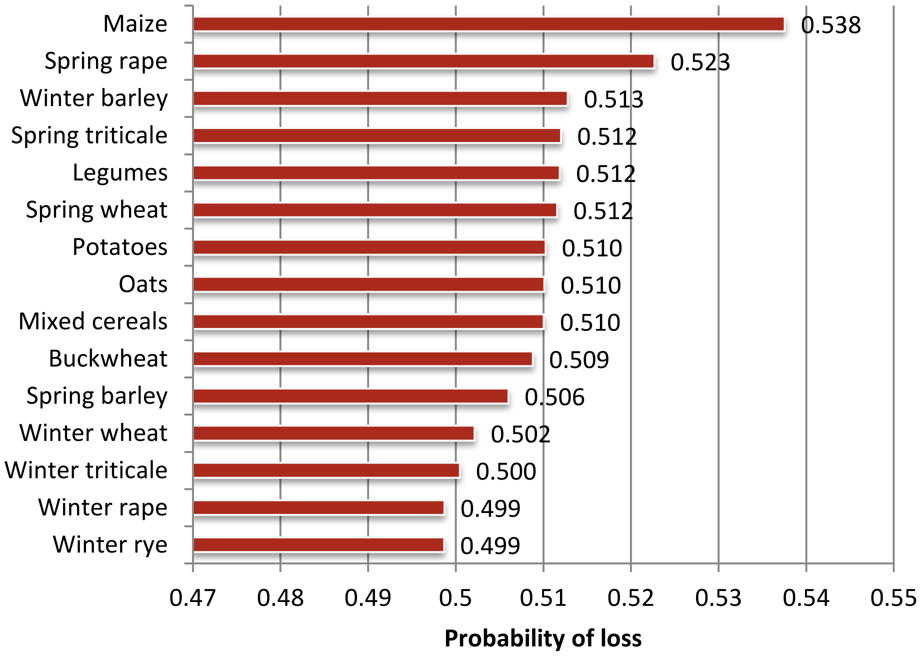


Fig. 7. Probability of loss for different crops (averages across counties) based on the normal distribution

The estimates based on the normal distribution (Fig. 7) suggest maize and spring rape are specific with the highest probabilities of yield loss (55.6% and 51.9%, respectively). This indicates the need for further introduction of new varieties and farming technologies that could increase cold acclimation of the said crops. Indeed, all the crops with exception of winter rape and winter rye, show the probabilities of loss exceeding 50%.

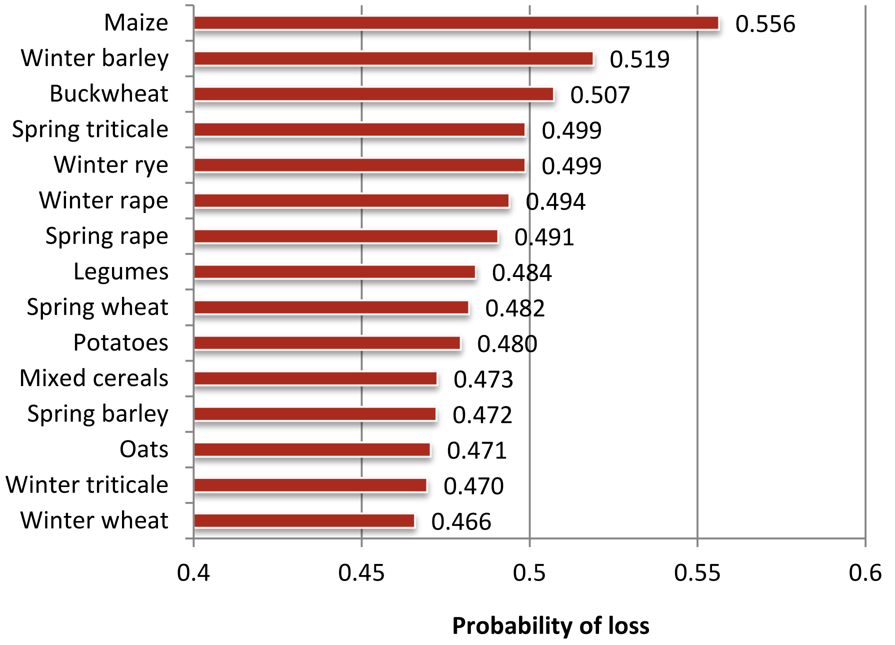


Fig. 8. Probability of yield loss for different crops (averages across counties) based on logistic distribution

The results based on the logistic distribution (Fig. 8) are somewhat different. Maize remained the most risky crop in terms of yield loss ratio. The most significant differences were observed for buckwheat, winter rye and winter rape, which ascended in ranks if compared to results based on the normal distribution. In addition, the logistic distribution yielded much wider range of the average probabilities if compared to the normal distribution. In order to reveal spatial differences which might be important for strategic decision making, we further look at county-level estimates for different crops.

Tables 8-22 below present the measures of risk for different crops across counties. Specifically, each table presents probability of yield loss, probabilities of hazard and mean hazard. Each of these is estimated on the basis of the normal and the logistic distribution. This information is helpful in defining region-specific support measures accounting for regional differences in crop yield risk.

Table 8. The measures of yield risk for winter wheat

County	**Probability of loss**	**Probability of hazard**				**Mean hazard**
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.511	0.239	0.090	0.017	0.002	0.048
Kaunas	0.502	0.222	0.103	0.029	0.005	0.053
Klaipėda	0.494	0.181	0.119	0.059	0.031	0.072
Marijampolė	0.498	0.232	0.086	0.016	0.002	0.046
Panevėžys	0.498	0.189	0.119	0.055	0.025	0.069
Šiauliai	0.500	0.212	0.110	0.037	0.009	0.058
Tauragė	0.506	0.232	0.095	0.021	0.003	0.050
Telšiai	0.503	0.214	0.111	0.037	0.009	0.058
Utena	0.511	0.208	0.118	0.046	0.014	0.064
Vilnius	0.499	0.206	0.113	0.042	0.012	0.061
Average	**0.502**	**0.213**	**0.106**	**0.036**	**0.011**	**0.058**
	Logistic distribution					
Alytus	0.494	0.222	0.071	0.017	0.005	0.044
Kaunas	0.466	0.202	0.079	0.024	0.010	0.047
Klaipėda	0.435	0.165	0.090	0.041	0.029	0.059
Marijampolė	0.443	0.196	0.058	0.014	0.004	0.037
Panevėžys	0.457	0.180	0.093	0.040	0.024	0.058
Šiauliai	0.468	0.200	0.084	0.028	0.012	0.050
Tauragė	0.470	0.207	0.073	0.020	0.007	0.044
Telšiai	0.495	0.204	0.098	0.037	0.019	0.059
Utena	0.467	0.194	0.089	0.033	0.016	0.054
Vilnius	0.463	0.194	0.086	0.031	0.015	0.052
Average	**0.466**	**0.197**	**0.082**	**0.029**	**0.014**	**0.050**

Table 9. The measures of yield risk for winter triticale

County	**Probability of loss**	**Probability of hazard**				**Mean hazard**
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.505	0.230	0.096	0.022	0.003	0.050
Kaunas	0.502	0.230	0.093	0.020	0.003	0.049
Klaipėda	0.500	0.179	0.121	0.063	0.035	0.075
Marijampolė	0.510	0.223	0.108	0.032	0.006	0.056
Panevėžys	0.501	0.186	0.120	0.058	0.028	0.071
Šiauliai	0.497	0.204	0.113	0.042	0.013	0.061
Tauragė	0.496	0.213	0.107	0.034	0.008	0.056
Telšiai	0.488	0.213	0.102	0.030	0.006	0.053
Utena	0.502	0.176	0.121	0.065	0.039	0.077
Vilnius	0.506	0.203	0.118	0.047	0.016	0.065
Average	**0.500**	**0.206**	**0.110**	**0.041**	**0.016**	**0.061**
	Logistic distribution					
Alytus	0.494	0.217	0.083	0.024	0.009	0.049
Kaunas	0.484	0.216	0.074	0.020	0.006	0.045
Klaipėda	0.466	0.177	0.099	0.045	0.032	0.064
Marijampolė	0.451	0.198	0.070	0.020	0.007	0.042
Panevėžys	0.455	0.179	0.093	0.040	0.025	0.059
Šiauliai	0.481	0.199	0.094	0.035	0.018	0.056
Tauragė	0.467	0.197	0.086	0.030	0.014	0.051
Telšiai	0.476	0.201	0.089	0.031	0.014	0.053
Utena	0.458	0.173	0.097	0.046	0.033	0.063
Vilnius	0.462	0.193	0.087	0.032	0.016	0.052
Average	**0.470**	**0.195**	**0.087**	**0.032**	**0.017**	**0.054**

Table 10. The measures of yield risk for winter rye

County	Probability of loss	Probability of hazard				Mean hazard
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.512	0.215	0.116	0.041	0.011	0.061
Kaunas	0.497	0.218	0.103	0.030	0.006	0.054
Klaipėda	0.496	0.186	0.119	0.057	0.027	0.070
Marijampolė	0.498	0.235	0.079	0.013	0.001	0.044
Panevėžys	0.501	0.215	0.109	0.035	0.008	0.057
Šiauliai	0.498	0.199	0.116	0.047	0.016	0.064
Tauragė	0.488	0.208	0.105	0.034	0.008	0.055
Telšiai	0.495	0.227	0.022	0.000	0.000	0.027
Utena	0.496	0.220	0.101	0.027	0.005	0.052
Vilnius	0.506	0.230	0.097	0.023	0.003	0.050
Average	**0.499**	**0.215**	**0.097**	**0.031**	**0.009**	**0.053**
	Logistic distribution					
Alytus	0.537	0.223	0.111	0.042	0.021	0.065
Kaunas	0.503	0.221	0.086	0.026	0.010	0.051
Klaipėda	0.492	0.188	0.106	0.048	0.033	0.068
Marijampolė	0.476	0.214	0.064	0.015	0.004	0.040
Panevėžys	0.495	0.210	0.094	0.033	0.015	0.056
Šiauliai	0.510	0.203	0.107	0.045	0.026	0.066
Tauragė	0.468	0.199	0.085	0.029	0.013	0.051
Telšiai	0.523	0.223	0.029	0.003	0.000	0.029
Utena	0.505	0.216	0.095	0.032	0.014	0.056
Vilnius	0.479	0.213	0.073	0.020	0.007	0.044
Average	**0.499**	**0.211**	**0.085**	**0.029**	**0.014**	**0.053**

Table 11. The measures of yield risk for winter barley

County	Probability of loss	Probability of hazard				Mean hazard
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.507	0.139	0.114	0.081	0.099	0.101
Kaunas	0.503	0.189	0.121	0.057	0.026	0.071
Klaipėda	0.499	0.150	0.117	0.077	0.075	0.091
Marijampolė	0.509	0.197	0.121	0.054	0.022	0.069
Panevėžys	0.512	0.154	0.120	0.079	0.076	0.093
Šiauliai	0.524	0.242	0.099	0.021	0.003	0.051
Tauragė	0.498	0.174	0.120	0.066	0.041	0.077
Telšiai	0.526	0.189	0.129	0.067	0.036	0.079
Utena	0.531	0.139	0.117	0.087	0.115	0.109
Vilnius	0.518	0.182	0.127	0.068	0.040	0.080
Average	**0.513**	**0.175**	**0.118**	**0.066**	**0.053**	**0.082**
	Logistic distribution					
Alytus	0.519	0.153	0.115	0.074	0.093	0.098
Kaunas	0.507	0.191	0.111	0.052	0.037	0.072
Klaipėda	0.515	0.161	0.116	0.070	0.078	0.092
Marijampolė	0.508	0.194	0.111	0.051	0.034	0.070
Panevėžys	0.509	0.160	0.114	0.069	0.076	0.090
Šiauliai	0.541	0.245	0.089	0.024	0.008	0.052
Tauragė	0.521	0.185	0.118	0.061	0.049	0.080
Telšiai	0.533	0.192	0.121	0.061	0.047	0.081
Utena	0.513	0.144	0.111	0.075	0.105	0.101
Vilnius	0.522	0.184	0.118	0.062	0.051	0.081
Average	**0.519**	**0.181**	**0.113**	**0.060**	**0.058**	**0.082**

Table 12. The measures of yield risk for spring wheat

County	Probability of loss	Probability of hazard				Mean hazard
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.532	0.242	0.105	0.025	0.004	0.054
Kaunas	0.518	0.250	0.073	0.009	0.000	0.042
Klaipėda	0.504	0.222	0.104	0.029	0.006	0.054
Marijampolė	0.516	0.249	0.039	0.002	0.000	0.033
Panevėžys	0.521	0.245	0.090	0.017	0.002	0.048
Šiauliai	0.517	0.244	0.087	0.015	0.001	0.047
Tauragė	0.495	0.236	0.036	0.001	0.000	0.031
Telšiai	0.511	0.236	0.093	0.019	0.002	0.049
Utena	0.506	0.227	0.100	0.025	0.004	0.052
Vilnius	0.498	0.238	0.072	0.010	0.001	0.041
Average	**0.512**	**0.239**	**0.080**	**0.015**	**0.002**	**0.045**
	Logistic distribution					
Alytus	0.499	0.223	0.078	0.021	0.007	0.047
Kaunas	0.474	0.211	0.048	0.009	0.002	0.034
Klaipėda	0.493	0.216	0.083	0.025	0.009	0.050
Marijampolė	0.511	0.229	0.045	0.007	0.001	0.034
Panevėžys	0.476	0.213	0.051	0.010	0.002	0.035
Šiauliai	0.465	0.208	0.056	0.012	0.003	0.037
Tauragė	0.504	0.224	0.041	0.006	0.001	0.033
Telšiai	0.462	0.205	0.064	0.016	0.005	0.040
Utena	0.505	0.222	0.088	0.027	0.010	0.052
Vilnius	0.431	0.188	0.044	0.008	0.002	0.031
Average	**0.482**	**0.214**	**0.060**	**0.014**	**0.004**	**0.039**

Table 13. The measures of yield risk for spring barley

County	Probability of loss	Probability of hazard				Mean hazard
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.517	0.208	0.121	0.049	0.016	0.066
Kaunas	0.503	0.243	0.058	0.005	0.000	0.038
Klaipėda	0.507	0.236	0.090	0.018	0.002	0.048
Marijampolė	0.503	0.237	0.029	0.001	0.000	0.030
Panevėžys	0.506	0.237	0.086	0.016	0.002	0.046
Šiauliai	0.503	0.244	0.056	0.005	0.000	0.037
Tauragė	0.500	0.239	0.075	0.011	0.001	0.042
Telšiai	0.514	0.245	0.033	0.001	0.000	0.031
Utena	0.500	0.209	0.112	0.040	0.011	0.060
Vilnius	0.508	0.233	0.095	0.021	0.003	0.050
Average	**0.506**	**0.233**	**0.076**	**0.017**	**0.003**	**0.045**
	Logistic distribution					
Alytus	0.503	0.201	0.105	0.043	0.025	0.064
Kaunas	0.461	0.204	0.045	0.008	0.002	0.032
Klaipėda	0.519	0.237	0.070	0.016	0.004	0.044
Marijampolė	0.471	0.198	0.029	0.003	0.000	0.027
Panevėžys	0.451	0.200	0.059	0.014	0.004	0.037
Šiauliai	0.457	0.201	0.044	0.008	0.001	0.032
Tauragė	0.483	0.218	0.058	0.012	0.003	0.038
Telšiai	0.491	0.207	0.028	0.003	0.000	0.027
Utena	0.449	0.188	0.082	0.029	0.013	0.049
Vilnius	0.437	0.193	0.058	0.014	0.004	0.037
Average	**0.472**	**0.205**	**0.058**	**0.015**	**0.006**	**0.039**

Table 14. The measures of yield risk for spring triticale

County	**Probability of loss**	**Probability of hazard**				**Mean hazard**
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.527	0.177	0.129	0.074	0.050	0.086
Kaunas	0.524	0.241	0.100	0.022	0.003	0.052
Klaipėda	0.511	0.216	0.114	0.039	0.010	0.060
Marijampolė	0.504	0.224	0.103	0.028	0.005	0.053
Panevėžys	0.503	0.223	0.102	0.028	0.005	0.053
Šiauliai	0.491	0.195	0.114	0.048	0.017	0.064
Tauragė	0.512	0.224	0.109	0.032	0.007	0.056
Telšiai	0.534	0.249	0.097	0.019	0.002	0.051
Utena	0.507	0.194	0.121	0.055	0.023	0.070
Vilnius	0.507	0.215	0.112	0.038	0.009	0.059
Average	**0.512**	**0.216**	**0.110**	**0.038**	**0.013**	**0.060**
	Logistic distribution					
Alytus	0.553	0.196	0.128	0.066	0.053	0.086
Kaunas	0.540	0.243	0.091	0.025	0.008	0.053
Klaipėda	0.498	0.213	0.092	0.031	0.013	0.054
Marijampolė	0.516	0.224	0.094	0.030	0.012	0.055
Panevėžys	0.451	0.198	0.070	0.020	0.007	0.042
Šiauliai	0.485	0.190	0.102	0.044	0.027	0.063
Tauragė	0.553	0.238	0.109	0.037	0.016	0.063
Telšiai	0.480	0.216	0.063	0.014	0.004	0.040
Utena	0.457	0.178	0.094	0.041	0.026	0.060
Vilnius	0.455	0.195	0.078	0.025	0.010	0.047
Average	**0.499**	**0.209**	**0.092**	**0.033**	**0.018**	**0.056**

Table 15. The measures of yield risk for oats

County	**Probability of loss**	**Probability of hazard**				**Mean hazard**
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.517	0.208	0.121	0.048	0.016	0.066
Kaunas	0.511	0.224	0.108	0.032	0.006	0.056
Klaipėda	0.505	0.218	0.109	0.034	0.007	0.057
Marijampolė	0.514	0.217	0.115	0.040	0.010	0.061
Panevėžys	0.516	0.211	0.120	0.046	0.014	0.064
Šiauliai	0.500	0.213	0.110	0.036	0.009	0.058
Tauragė	0.523	0.231	0.110	0.031	0.006	0.057
Telšiai	0.507	0.210	0.115	0.042	0.012	0.062
Utena	0.499	0.201	0.116	0.046	0.015	0.063
Vilnius	0.510	0.200	0.121	0.052	0.020	0.068
Average	**0.510**	**0.213**	**0.114**	**0.041**	**0.012**	**0.061**
	Logistic distribution					
Alytus	0.506	0.211	0.100	0.037	0.018	0.060
Kaunas	0.477	0.206	0.082	0.026	0.010	0.049
Klaipėda	0.479	0.210	0.080	0.024	0.009	0.048
Marijampolė	0.455	0.195	0.079	0.025	0.011	0.047
Panevėžys	0.479	0.201	0.091	0.032	0.015	0.054
Šiauliai	0.460	0.195	0.083	0.029	0.013	0.050
Tauragė	0.497	0.217	0.086	0.027	0.010	0.051
Telšiai	0.464	0.196	0.085	0.029	0.014	0.051
Utena	0.457	0.190	0.086	0.032	0.016	0.052
Vilnius	0.432	0.182	0.076	0.026	0.012	0.046
Average	**0.471**	**0.200**	**0.085**	**0.029**	**0.013**	**0.051**

Table 16. The measures of yield risk for buckwheat

County	Probability of loss	Probability of hazard				Mean hazard
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.513	0.162	0.123	0.076	0.063	0.089
Kaunas	0.513	0.178	0.125	0.069	0.043	0.080
Klaipėda	0.492	0.140	0.112	0.077	0.088	0.095
Marijampolė	0.526	0.182	0.129	0.071	0.044	0.083
Panevėžys	0.505	0.163	0.121	0.073	0.058	0.086
Šiauliai	0.517	0.101	0.093	0.079	0.191	0.129
Tauragė	0.512	0.156	0.121	0.078	0.071	0.092
Telšiai	0.509	0.128	0.109	0.083	0.124	0.109
Utena	0.498	0.160	0.119	0.073	0.059	0.085
Vilnius	0.504	0.167	0.121	0.071	0.051	0.083
Average	**0.509**	**0.154**	**0.117**	**0.075**	**0.079**	**0.093**
	Logistic distribution					
Alytus	0.540	0.187	0.124	0.066	0.057	0.086
Kaunas	0.458	0.174	0.097	0.045	0.031	0.063
Klaipėda	0.481	0.153	0.107	0.064	0.071	0.084
Marijampolė	0.512	0.185	0.115	0.058	0.046	0.077
Panevėžys	0.489	0.179	0.108	0.053	0.041	0.072
Šiauliai	0.542	0.111	0.099	0.081	0.195	0.133
Tauragė	0.528	0.178	0.121	0.067	0.062	0.087
Telšiai	0.491	0.131	0.103	0.072	0.113	0.100
Utena	0.488	0.161	0.109	0.062	0.062	0.081
Vilnius	0.543	0.195	0.124	0.063	0.049	0.083
Average	**0.507**	**0.165**	**0.111**	**0.063**	**0.073**	**0.087**

Table 17. The measures of yield risk for mixed cereals

County	Probability of loss	Probability of hazard				Mean hazard
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.521	0.201	0.125	0.056	0.023	0.071
Kaunas	0.529	0.208	0.127	0.054	0.019	0.070
Klaipėda	0.487	0.161	0.116	0.068	0.050	0.080
Marijampolė	0.514	0.236	0.097	0.022	0.003	0.051
Panevėžys	0.509	0.193	0.122	0.057	0.025	0.071
Šiauliai	0.499	0.206	0.114	0.042	0.013	0.061
Tauragė	0.512	0.214	0.115	0.041	0.011	0.061
Telšiai	0.522	0.245	0.091	0.017	0.002	0.048
Utena	0.500	0.201	0.116	0.046	0.016	0.063
Vilnius	0.508	0.188	0.123	0.060	0.029	0.073
Average	**0.510**	**0.205**	**0.115**	**0.046**	**0.019**	**0.065**
	Logistic distribution					
Alytus	0.461	0.188	0.091	0.035	0.019	0.055
Kaunas	0.484	0.198	0.097	0.038	0.020	0.058
Klaipėda	0.477	0.170	0.105	0.054	0.045	0.072
Marijampolė	0.484	0.218	0.064	0.015	0.004	0.041
Panevėžys	0.446	0.174	0.091	0.039	0.025	0.057
Šiauliai	0.428	0.181	0.074	0.025	0.011	0.045
Tauragė	0.498	0.208	0.097	0.035	0.017	0.058
Telšiai	0.542	0.245	0.089	0.024	0.008	0.052
Utena	0.468	0.190	0.093	0.037	0.020	0.057
Vilnius	0.439	0.180	0.083	0.032	0.017	0.051
Average	**0.473**	**0.195**	**0.088**	**0.033**	**0.019**	**0.055**

Table 18. The measures of yield risk for maize

County	Probability of loss	Probability of hazard				Mean hazard
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.525	0.202	0.127	0.057	0.024	0.072
Kaunas	0.514	0.189	0.125	0.061	0.030	0.074
Klaipėda	0.585	0.110	0.104	0.091	0.226	0.149
Marijampolė	0.506	0.229	0.099	0.024	0.004	0.051
Panevėžys	0.520	0.133	0.113	0.085	0.120	0.109
Šiauliai	0.524	0.139	0.116	0.085	0.111	0.107
Tauragė	0.576	0.180	0.141	0.089	0.072	0.102
Telšiai	0.577	0.157	0.133	0.096	0.111	0.115
Utena	0.530	0.065	0.064	0.060	0.308	0.161
Vilnius	0.517	0.119	0.105	0.083	0.148	0.117
Average	**0.538**	**0.152**	**0.113**	**0.073**	**0.115**	**0.106**
	Logistic distribution					
Alytus	0.514	0.206	0.108	0.044	0.025	0.066
Kaunas	0.531	0.211	0.114	0.048	0.028	0.070
Klaipėda	0.593	0.119	0.110	0.091	0.213	0.147
Marijampolė	0.477	0.212	0.072	0.019	0.006	0.044
Panevėžys	0.518	0.144	0.112	0.076	0.107	0.103
Šiauliai	0.560	0.151	0.123	0.085	0.123	0.114
Tauragė	0.679	0.247	0.172	0.084	0.054	0.106
Telšiai	0.586	0.160	0.131	0.090	0.122	0.118
Utena	0.578	0.078	0.077	0.071	0.313	0.170
Vilnius	0.527	0.135	0.110	0.080	0.131	0.112
Average	**0.556**	**0.166**	**0.113**	**0.069**	**0.112**	**0.105**

Table 19. The measures of yield risk for legumes

County	Probability of loss	Probability of hazard				Mean hazard
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.512	0.164	0.123	0.075	0.059	0.087
Kaunas	0.514	0.227	0.107	0.030	0.006	0.055
Klaipėda	0.499	0.190	0.119	0.055	0.024	0.069
Marijampolė	0.509	0.216	0.112	0.037	0.009	0.059
Panevėžys	0.507	0.184	0.123	0.062	0.033	0.075
Šiauliai	0.500	0.209	0.112	0.040	0.011	0.060
Tauragė	0.522	0.254	0.044	0.002	0.000	0.035
Telšiai	0.523	0.209	0.124	0.050	0.017	0.068
Utena	0.523	0.189	0.128	0.066	0.035	0.078
Vilnius	0.510	0.179	0.124	0.067	0.040	0.079
Average	**0.512**	**0.202**	**0.112**	**0.048**	**0.023**	**0.066**
	Logistic distribution					
Alytus	0.513	0.173	0.116	0.065	0.060	0.084
Kaunas	0.493	0.216	0.083	0.025	0.009	0.049
Klaipėda	0.465	0.193	0.089	0.033	0.017	0.054
Marijampolė	0.465	0.201	0.080	0.025	0.010	0.048
Panevėžys	0.464	0.184	0.095	0.040	0.024	0.059
Šiauliai	0.440	0.187	0.077	0.026	0.011	0.046
Tauragė	0.503	0.225	0.045	0.007	0.001	0.034
Telšiai	0.510	0.210	0.103	0.039	0.020	0.062
Utena	0.513	0.206	0.108	0.044	0.025	0.066
Vilnius	0.475	0.180	0.101	0.047	0.033	0.065
Average	**0.484**	**0.197**	**0.090**	**0.035**	**0.021**	**0.057**

Table 20. The measures of yield risk for winter rape

County	Probability of loss	Probability of hazard				Mean hazard
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.508	0.159	0.121	0.076	0.066	0.089
Kaunas	0.492	0.183	0.118	0.057	0.028	0.070
Klaipėda	0.501	0.150	0.117	0.077	0.075	0.092
Marijampolė	0.493	0.167	0.119	0.068	0.046	0.079
Panevėžys	0.492	0.142	0.113	0.077	0.083	0.093
Šiauliai	0.493	0.204	0.111	0.041	0.012	0.060
Tauragė	0.493	0.152	0.116	0.074	0.067	0.087
Telšiai	0.502	0.177	0.121	0.065	0.038	0.077
Utena	0.489	0.125	0.105	0.078	0.115	0.103
Vilnius	0.524	0.176	0.128	0.074	0.051	0.086
Average	**0.499**	**0.163**	**0.117**	**0.069**	**0.058**	**0.084**
	Logistic distribution					
Alytus	0.488	0.161	0.109	0.062	0.062	0.081
Kaunas	0.491	0.181	0.108	0.053	0.040	0.072
Klaipėda	0.479	0.156	0.106	0.062	0.064	0.081
Marijampolė	0.479	0.165	0.106	0.057	0.052	0.076
Panevėžys	0.503	0.145	0.110	0.072	0.097	0.097
Šiauliai	0.496	0.208	0.096	0.034	0.016	0.057
Tauragė	0.492	0.152	0.109	0.067	0.077	0.088
Telšiai	0.507	0.194	0.110	0.050	0.033	0.070
Utena	0.472	0.128	0.099	0.068	0.106	0.095
Vilnius	0.533	0.188	0.122	0.064	0.052	0.083
Average	**0.494**	**0.168**	**0.107**	**0.059**	**0.060**	**0.080**

Table 21. The measures of yield risk for spring rape

County	Probability of loss	Probability of hazard				Mean hazard
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.519	0.218	0.117	0.041	0.011	0.062
Kaunas	0.530	0.250	0.092	0.017	0.002	0.049
Klaipėda	0.533	0.200	0.130	0.062	0.028	0.076
Marijampolė	0.513	0.250	0.053	0.004	0.000	0.037
Panevėžys	0.524	0.196	0.128	0.061	0.028	0.075
Šiauliai	0.514	0.225	0.109	0.032	0.006	0.057
Tauragė	0.537	0.263	0.064	0.006	0.000	0.041
Telšiai	0.515	0.216	0.116	0.040	0.010	0.061
Utena	0.508	0.169	0.123	0.072	0.052	0.084
Vilnius	0.535	0.214	0.127	0.052	0.017	0.069
Average	**0.523**	**0.220**	**0.106**	**0.039**	**0.015**	**0.061**
	Logistic distribution					
Alytus	0.510	0.210	0.103	0.040	0.021	0.062
Kaunas	0.479	0.215	0.064	0.015	0.004	0.040
Klaipėda	0.519	0.208	0.110	0.045	0.026	0.067
Marijampolė	0.502	0.226	0.049	0.008	0.002	0.035
Panevėžys	0.450	0.187	0.085	0.031	0.016	0.051
Šiauliai	0.456	0.199	0.073	0.021	0.008	0.044
Tauragė	0.519	0.237	0.057	0.010	0.002	0.039
Telšiai	0.491	0.203	0.097	0.036	0.019	0.058
Utena	0.444	0.166	0.094	0.045	0.033	0.062
Vilnius	0.534	0.212	0.115	0.048	0.028	0.070
Average	**0.491**	**0.206**	**0.085**	**0.030**	**0.016**	**0.053**

Table 22. The measures of yield risk for potatoes

County	Probability of loss	Probability of hazard				Mean hazard
		Low hazard	Medium hazard	High hazard	Catastrophic hazard	
	Normal distribution					
Alytus	0.528	0.200	0.128	0.060	0.026	0.074
Kaunas	0.509	0.222	0.108	0.032	0.006	0.056
Klaipėda	0.507	0.187	0.123	0.060	0.030	0.073
Marijampolė	0.513	0.221	0.111	0.035	0.008	0.058
Panevėžys	0.506	0.236	0.088	0.017	0.002	0.047
Šiauliai	0.505	0.180	0.122	0.064	0.036	0.076
Tauragė	0.512	0.187	0.124	0.062	0.032	0.075
Telšiai	0.519	0.229	0.109	0.031	0.006	0.056
Utena	0.495	0.214	0.106	0.033	0.007	0.055
Vilnius	0.509	0.234	0.095	0.021	0.003	0.050
Average	**0.510**	**0.211**	**0.111**	**0.041**	**0.016**	**0.062**
	Logistic distribution					
Alytus	0.514	0.197	0.112	0.051	0.034	0.071
Kaunas	0.479	0.207	0.083	0.026	0.011	0.050
Klaipėda	0.453	0.176	0.093	0.041	0.027	0.059
Marijampolė	0.522	0.217	0.105	0.039	0.020	0.062
Panevėžys	0.498	0.224	0.071	0.017	0.005	0.044
Šiauliai	0.438	0.166	0.091	0.042	0.030	0.059
Tauragė	0.510	0.190	0.113	0.054	0.039	0.073
Telšiai	0.477	0.207	0.082	0.025	0.010	0.049
Utena	0.435	0.185	0.075	0.025	0.011	0.045
Vilnius	0.471	0.209	0.070	0.018	0.006	0.043
Average	**0.480**	**0.198**	**0.090**	**0.034**	**0.019**	**0.056**

The normal and the logistic distributions suggest that the mean probabilities of yield loss are 50.2% and 46.6%, respectively, for winter wheat (Table 8). Alytus and Utena counties show the highest probabilities of yield loss in case of the normal distribution. As for the logistic distribution, Alytus and Telšiai counties are specific with highest probabilities of yield loss. The mean probability of low hazard is 21.3% and 19.7% depending on distribution assumed which implies that hazard of such a degree is likely to occur every 4.7-5.1 years on average. Looking at catastrophic hazard, it is likely to occur every 70-90 years on average. Irrespectively of the distribution assumed Klaipėda and Panevėžys counties featured the highest probability of the catastrophic hazard. Accordingly, the highest values of the mean hazard were also observed for latter two counties.

Marijampolė, Vilnius and Alytus counties are specific with the highest probabilities of yield loss for winter triticale under the normal distribution (Table 9). Alytus, Kaunas and Tauragė counties show the highest probability under the logistic distribution. The average probabilities of the catastrophic hazard are 1.6% and 1.7% under the normal and logistic distributions, respectively, which implies the occurrence of such events every 60 years on average. The highest probability of the catastrophic hazard is observed for Utena, Klaipėda and Panevėžys counties independently of the distribution applied. The latter counties also showed the highest levels of mean hazard.

Considering winter rye (Table 10), Alytus and Vilnius counties show the highest probabilities of yield loss according to the normal distribution yet Alytus and Telšiai Kaunas are specific with the highest probabilities according to the logistic distribution. The average probabilities of the low hazard are rather similar across the two distributions whereas, logistic distribution suggests higher average risk of the catastrophic hazard if opposed to the normal distribution. Accordingly the catastrophic hazard is likely to occur every 111 (resp. 71) years.

The results for winter barley (Table 11) are highly similar across the normal and the logistic distributions. Šiauliai and Telšiai counties show the highest probabilities of loss according to both distributions whereas Utena county features the highest risk only if the normal distribution is considered. The highest catastrophic risk is observed for Alytus and Utena counties irrespectively of the distribution. Specifically, these counties exhibit probabilities of the catastrophic hazard close to 10%, which implies the occurrence of such events every ten years. The average probabilities of the catastrophic hazard are 5.3% and 5.8% for the normal and the logistic distributions, respectively. The highest mean hazard of some 10% was observed for Alytus and Utena counties under both distributions.

Application of the two distributions yielded rather divergent conclusions for spring wheat (Table 12). Alytus and Panevėžys counties feature the highest probabilities of yield loss according to the normal distribution, whereas Marijampolė, Utena and Tauragė counties show the highest probabilities according logistic distribution. The highest probabilities of the catastrophic hazard are observed for Alytus and Klaipėda counties. The average probabilities of the catastrophic hazard are 0.2% and 0.4% according the normal and the logistic distribution, respectively. Klaipėda and Utena counties show the highest mean hazards exceeding 5% irrespectively of the distribution assumed.

Alytus and Telšiai counties are specific with the highest probabilities of yield loss under the normal distribution for spring barley (Table 13). The logistic distribution suggests Klaipėda and Alytus counties as those showing the highest probability of yield loss. Alytus county also shows the highest of the catastrophic hazard. The average probabilities of catastrophic hazard are 0.3% and 0.6% according to the normal and logistic distributions, respectively. Utena county appears as yet another county showing high probability of catastrophic hazard. Consequently, Alyus and Utena counties featured the highest values of mean hazard.

As regards spring triticale (Table 14), Alytus and Kaunas counties show the highest probabilities of yield loss under both distributions, whereas Tauragė county is exceptional in this regard under the logistic distribution only. Alytus county also shows the highest probability of the catastrophic hazard (some 5%). The remaining counties show much lower probabilities of the catastrophic hazard, e.g. 2.3% for Utena county. The average of mean hazard is 6% or 5.6% depending of the distribution assumed.

Alytus and Tauragė counties are specific with the highest probabilities of loss in oat yield under both the normal and the logistic distributions (Table 15). Under the normal distribution, Vilnius county shows the highest risk of the catastrophic hazard, i.e. 2%. Panevėžys, Utena and Alytus counties show lower probabilities of the catastrophic hazard, ranging in between 1.4 and 1.6%. As for the logistic distribution the latter three counties showed the highest probabilities of the catastrophic hazard. Alytus county shows the highest mean hazard under the logistic distribution, whereas the second highest under the normal distribution. Indeed, Vilnius county shows the highest mean hazard under the normal distribution.

Marijampolė and Šiauliai counties are specific with the highest probabilities of the buckwheat yield loss (Table 16). Vilnius, Šiauliai and Alytus counties show the highest probabilities of yield loss. The average probabilities of the catastrophic hazard are 7.9% and 7.3% according to the normal and the logistic distributions, respectively. The latter figures imply the occurrence of the catastrophic hazard every 12.7 and 13.7 years. Irrespectively of the distribution, Šiauliai and Telšiai counties exhibit the highest probabilities of the catastrophic hazard as well as the highest levels of the mean hazard.

As regards mixed cereals, Kaunas, Telšiai and Alytus counties featured the highest probabilities of yield loss under the normal distribution (Table 17). Looking at the results for the logistic distribution, Telšiai county shows the highest probability of yield loss (54.2%), while the second highest probability is observed for Tauragė county (49.8%). The average probability of catastrophic hazard is 1.9% respectively of the distribution. The highest probability of the catastrophic hazard is observed for Klaipėda county (some 5%).

Maize shows the highest probabilities of yield loss among the crops analysed for both the normal and the logistic distributions (Table 18). Looking at individual counties, Klaipėda, Tauragė and Telšiai counties are those showing the highest probabilities of yield loss. This probability is especially high for Tauragė county under the logistic distribution (67.9%). The average probability of the catastrophic hazard is rather high if compare to those of lower degrees of hazard. This indicates that the underlying distributions are rather flat and heavy-tailed. The probabilities of the catastrophic hazard for Utena county exceed 30%. The same probability exceeded 20% for Klaipėda county. The average probabilities of the catastrophic hazard are close to 11% and indicate occurrence of such hazards every 9 years. Klaipėda and Utena show the highest levels of the mean hazard.

Utena, Telšiai and Tauragė counties are specific with the highest probabilities of legume yield loss under the normal distribution (Table 19). As for the logistic distribution, Utena, Telšiai and Alytus counties show the highest probabilities of yield loss. The average probabilities of the catastrophic hazard are rather low, namely some 2%. The highest probability of the catastrophic hazard is observed for Alytus county (6%). The latter county is also specific with the highest level of the mean hazard.

Focusing on winter rape, Vilnius county shows the highest probability of yield loss (Table 20). The highest risk of the catastrophic hazard is observed for Panevėžys and Utena counties (over 8%). The average probability of the catastrophic hazard is close to 6%, which suggests the occurrence such a hazard every 17 years.

Spring rape shows similar probability of yield loss if compared to winter rape (Table 21). However, the average probabilities of the catastrophic hazard are rather low for the former crop. Specifically, the latter probability is some 1.5% indicating that catastrophic hazard is likely to occur every 66 year. Under the normal distribution Utena county appears as one featuring the highest probability of the catastrophic hazard (5.2%) along with highest level of the mean hazard of 8.4%. Application of the logistic distribution suggests that Utena, Vilnius and Klaipėda counties show the highest probabilities of the catastrophic hazard. Vilnius county shows the highest level of the mean hazard.

As regards potato yield, risk measures are highly similar across the counties under the normal distribution, yet more differences are more evident according to the logistic distribution (Table 22). Šiauliai, Tauragė and Klaipėda counties show the highest probabilities of the catastrophic hazard as suggested as a normal distribution. These and Alytus county features the highest levels of the mean hazard under the same distribution. Focusing on the logistic distribution, Tauragė and Alytus counties exhibit both the highest probabilities of the catastrophic hazard and the highest levels of the mean hazard.

The results indicate that there exists substantial variation in measures of risk across a counties analysed. This is due to regional differences in soil quality and meteorological conditions. Furthermore, these differences vary with the degree of risk. Therefore, policy measures can be adjusted to cope with hazards of different degrees in different regions. In this sub-section, we looked into measures of risk which ignored either the level of hazard or the mass of probabilities associated with extreme hazards. In the following sub-section, we apply yet another measure of risk, namely relative insurance premium.

3.3. Estimates of insurance premium

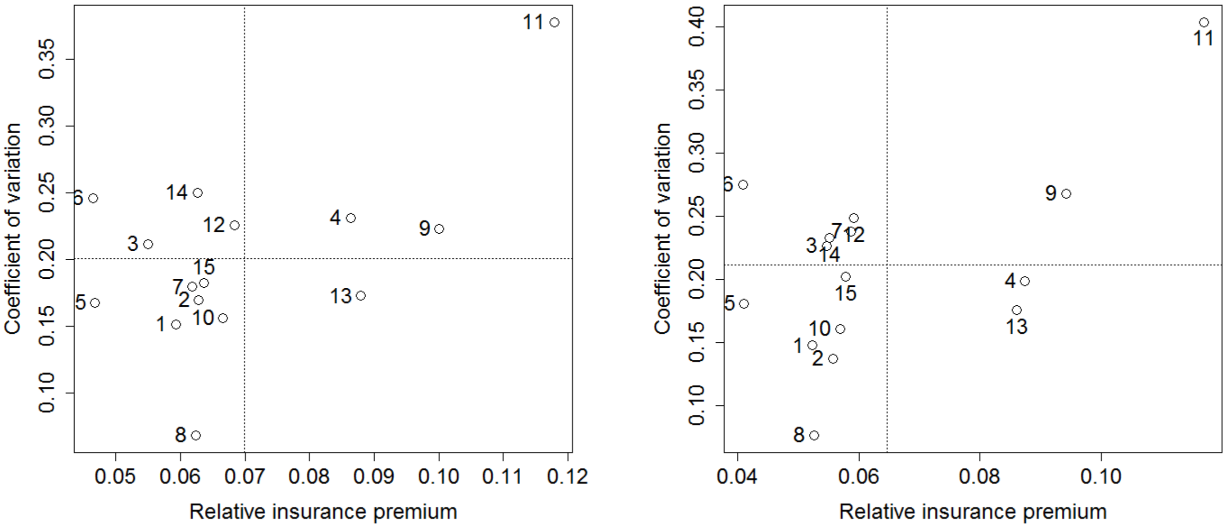
The relative risk premia are estimated in accordance with Eq. 18. In our setting, it measures the average loss of the expected yield. Comparison of the premium across the crops and regions can show the extent of the expected risk and, therefore, provide with insights in differences of the need for risk mitigation measures and insurance effectiveness. Table 23 presents the average insurance premia for each crop (averages were calculated across the counties).

Table 23. Average relative risk premia

	Normal distribution	Logistic distribution
Winter wheat	0.059	0.052
Winter triticale	0.063	0.056
Winter rye	0.055	0.055
Winter barley	0.086	0.087
Spring wheat	0.047	0.041
Spring barley	0.046	0.041
Spring triticale	0.062	0.059
Oats	0.062	0.053
Buckwheat	0.100	0.094
Mixed cereals	0.067	0.057
Maize	0.118	0.117
Legumes	0.068	0.059
Winter rape	0.088	0.086
Spring rape	0.063	0.055
Potatoes	0.064	0.058

The average insurance premia are rather similar across the normal distribution and the logistic distribution. Maize, buckwheat, winter barley and winter rape show the highest production risk as represented by the insurance premium. Indeed, the average risk premia for the latter crops exceed 8%. Spring wheat and spring barley are the least risky crops with insurance premia of less than 5%.

In order to relate production risk to its spatial variation, Fig. 9 presents a scatter plot for the average insurance premium and its coefficient of variation. Considering the average values of the latter two variables, the crops analysed can be grouped into the four categories. First, buckwheat and maize exhibit the highest production risk along with the highest valuation thereof. Accordingly, areas sown under these two crops need to be distributed across the counties in order minimize production risk. Otherwise, additional measures of crop insurance would be required in order to manage the resulting increase in production risk. Second, winter rape appears as a high-risk crop with relatively low spatial variation in production risk. This indicates that the varieties of winter rape currently cultivated in Lithuania only partial are suitable for Lithuanian meteorological conditions. Winter barley shows relatively high risk, however, its regional variation depends on the distribution assumed. Specifically, spatial variation increases under the normal distribution, if compared to the logistic distribution. Third, barley, winter rye, legumes and spring rape feature relatively low average production risk and relatively high spatial variation. This finding implies that certain regions require more intensive application of risk management measures. Fourth, winter wheat, winter triticale, spring wheat, oats, mixed cereals and potatoes exhibit the lowest risk and its variation across the counties. Spring wheat shows low risk level, yet its regional variation depends on the distribution applied for the analysis. The varieties of crops specific with low level of production risk can be considered as have been properly selected for Lithuania.



a – normal distribution *b – logistic distribution*

Fig. 9. Relationship between relative insurance premium and its spatial variation

Labels correspond to the following crops: 1 – winter wheat, 2 – winter triticale, 3 – winter rye, 4 – winter barley, 5 – spring wheat, 6 – spring barley, 7 – spring triticale, 8 – oats, 9 – buckwheat, 10 – mixed cereals, 11 – maize, 12 – legumes, 13 – winter rape, 14 – spring rape, 15 – potatoes.

In order to deliver further insights into regional differences in production risk, Tables 24 and 25 present relative insurance premia based on the normal and the logistic distributions respectively. As Fig. 9 suggested, certain crops show higher variation in production risk across regions. Therefore, it is more important to analyse the differences in production risk for the latter crops.

Maize showed the highest variation in insurance premia. Independently of statistical distribution, Utena county shows the highest risk insurance premium (some 20%). The lowest insurance premium is observed for Marijampolė county (some 5%). In addition, Alytus and Kaunas counties show relatively low insurance premia of around 7% for both distributions.

Buckwheat is yet another crop showing rather high insurance premium and high spatial differences. The highest insurance premia are observed for Šiauliai and Telšiai counties (some 15% and 12% respectively). The other counties are rather similar in terms of insurance premium with its values ranging in between 8.3% and 10.2%.

Winter and spring barley show substantial variation in insurance premia across counties however, the average insurance premium is much lower for spring barley. As regards winter barley, the highest insurance premia are observed for Utena and Alytus counties (over 10%). Klaipėda and Panevėžys counties also show high insurance premia exceeding 9%. Alytus county shows the highest insurance premium for spring barley (6.8% and 6.6% according to the normal and the logistic distributions respectively).

Klaipėda county exhibits the highest insurance premium for winter rye (7%). Alytus and Šiauliai counties show insurance premia exceeding 6%. The lowest insurance premium is observed for Telšiai county. Even though re-allocation of winter rye could lead to a decrease in production risk, the average level of the risk is relatively low and indicates a successful choice of varieties for Lithuania soil.

Alytus county featured the highest insurance premium for legumes (9% irrespectively of the distribution assumed). Utena and Vilnius counties come next in terms of ranking, but the absolute values of the risk premia differ across the statistical distributions. Specifically, the latter two counties show the insurance premia of some 8% under the normal distribution, whereas these values dropped to almost 7% under the logistic distribution. The lowest insurance risk is observed for Tauragė county (3.7% under the normal distribution).

Looking at results for spring rape, the ranking of counties differs across the two statistical distributions. According to the normal distribution, Utena county shows the highest insurance premium of 8.7%. As for the logistic distribution, the highest premium is observed for Vilnius county (7.3%). Under the normal distribution, Klaipėda, Panevėžys and Vilnius counties are specific with relatively high insurance premia exceeding 7%. Similarly, Alytus, Klaipėda and Utena counties show relatively high insurance premia exceeding 6%. The lowest insurance premia are observed for Marijampolė and Tauragė counties.

Table 24. Relative risk premia according to normal distribution

	Alytus	Kaunas	Klaipėda	Marijampolė	Panevėžys	Šiauliai	Tauragė	Telšiai	Utena	Vilnius
Winter wheat	0.049	0.055	0.074	0.047	0.071	0.059	0.051	0.059	0.065	0.062
Winter triticale	0.052	0.050	0.077	0.057	0.073	0.062	0.057	0.054	0.080	0.066
Winter rye	0.062	0.055	0.072	0.045	0.058	0.065	0.057	0.030	0.054	0.052
Winter barley	0.109	0.072	0.097	0.070	0.099	0.053	0.080	0.081	0.120	0.082
Spring wheat	0.055	0.044	0.055	0.035	0.050	0.048	0.033	0.050	0.053	0.043
Spring barley	0.068	0.039	0.049	0.032	0.048	0.039	0.044	0.034	0.061	0.051
Spring triticale	0.089	0.053	0.061	0.055	0.054	0.065	0.058	0.052	0.071	0.060
Oats	0.067	0.057	0.058	0.062	0.066	0.059	0.058	0.063	0.065	0.069
Buckwheat	0.093	0.083	0.102	0.085	0.089	0.155	0.097	0.121	0.089	0.086
Mixed cereals	0.073	0.071	0.083	0.052	0.073	0.062	0.062	0.050	0.065	0.075
Maize	0.074	0.076	0.180	0.053	0.121	0.117	0.106	0.124	0.193	0.134
Legumes	0.091	0.057	0.070	0.060	0.077	0.061	0.037	0.069	0.080	0.081
Winter rape	0.094	0.072	0.097	0.082	0.100	0.061	0.092	0.079	0.114	0.089
Spring rape	0.063	0.051	0.077	0.039	0.076	0.058	0.043	0.062	0.087	0.071
Potatoes	0.076	0.057	0.075	0.059	0.048	0.078	0.077	0.057	0.056	0.051

Table 25. Relative risk premia according to logistic distribution

	Alytus	Kaunas	Klaipėda	Marijampolė	Panevėžys	Šiauliai	Tauragė	Telšiai	Utena	Vilnius
Winter wheat	0.045	0.049	0.062	0.039	0.061	0.052	0.046	0.061	0.056	0.054
Winter triticale	0.051	0.047	0.067	0.044	0.061	0.058	0.053	0.055	0.067	0.054
Winter rye	0.068	0.053	0.071	0.042	0.058	0.068	0.053	0.032	0.058	0.046
Winter barley	0.107	0.075	0.099	0.073	0.097	0.054	0.085	0.085	0.112	0.086
Spring wheat	0.049	0.036	0.051	0.036	0.037	0.039	0.035	0.042	0.054	0.033
Spring barley	0.066	0.034	0.046	0.029	0.039	0.034	0.040	0.030	0.051	0.038
Spring triticale	0.091	0.055	0.056	0.057	0.044	0.066	0.065	0.042	0.062	0.049
Oats	0.062	0.051	0.049	0.049	0.056	0.052	0.053	0.053	0.054	0.048
Buckwheat	0.091	0.066	0.091	0.081	0.076	0.157	0.092	0.113	0.087	0.087
Mixed cereals	0.057	0.061	0.076	0.043	0.060	0.047	0.060	0.054	0.059	0.053
Maize	0.068	0.072	0.173	0.046	0.114	0.127	0.110	0.131	0.201	0.127
Legumes	0.090	0.051	0.056	0.050	0.061	0.048	0.036	0.064	0.068	0.069
Winter rape	0.087	0.075	0.087	0.081	0.107	0.059	0.096	0.073	0.107	0.088
Spring rape	0.064	0.042	0.069	0.038	0.053	0.046	0.041	0.060	0.065	0.073
Potatoes	0.074	0.051	0.062	0.065	0.046	0.062	0.077	0.051	0.047	0.044

Such crops as oats and winter wheat show relatively low CVs for the insurance premia. Accordingly, the range of insurance premium for oats is bounded by the minimum value of 4.8% for Vilnius county and the maximum value of 6.2% for Alytus county. As for winter wheat, minimum value is 3.9% (Marijampolė county) and the maximum value is 6.2% (Klaipėda county). The aggregate production risk for these crops cannot be decreased by means of re-allocation. However, introduction of more suitable varieties and technological innovations might lead to a country-wide reduction in risk.

In this sub-section, we looked at insurance premia for different crops and regions. This measure indicates the most likely degree of hazard. However, we did not account for importance of each region for cultivation of a certain crop. To do so, the next sub-section relates insurance premium and AAI.

3.4. Aggregate advantage index and risk premia

AAI describing the importance of (specialisation) of counties has been presented in Section 2.3. By relating the latter measure to the insurance premium, we seek to identify the key areas for improvement. For instance, highly important county with vast areas and/or high yield of a certain crop should face lower production risk in order to ensure sound situation of farms (especially, the specialised ones). In case such requirements are not met, insurance might be encouraged by means of support measures and advisory services. This sub-section, therefore, explores the patterns of production risk (as represented by the insurance premium) and specialisation (as represented by the AAI).

AAIs were calculated for each crop and county. The insurance premium was also estimated for the same dimensions, yet the two values were rendered by the normal and the logistic distributions. The latter two values were aggregated by means of geometric average. A linear trend was then estimated to capture the underlying relationships among the production risk and AAI. Table 26 presents the results.

Table 26. The relationship between AAI and production risk across the selected crops

Crop	Trend	Crop	Trend
Winter wheat	-0.017	**Winter rye**	0.001
Winter triticale	-0.023	**Spring triticale**	0.009
Winter barley	-0.059	**Oats**	0.002
Spring wheat	-0.018	**Mixed cereals**	0.006
Spring barley	-0.043	**Legumes**	0.006
Buckwheat	-0.014	**Potatoes**	0.015
Maize	-0.109		
Winter rape	-0.033		
Spring rape	-0.028		

The linear model included production risk as an independent variable, whereas AAI entered the model as a dependent one. Therefore, the coefficients in Table 26 show the changes in AAI due to increase in the insurance premiums by 1 p.p. The crops with negative coefficients are mainly located in less risky regions, while the opposite holds for those with positive coefficients. Generally, crops with positive coefficients of the trend feature lower average production risks (see Fig. 9). The highest positive coefficient is observed for potatoes indicating that the most important potato-producing counties are associated with the highest production risk.

A closer look into county-level data indicates certain deviations from the general trends. For winter triticale, Klaipėda county appears as one featuring both high AAI (1.15) and relatively high insurance premium (7.7% and 6.7% according to the normal and the logistic distributions, respectively). Alytus county demands much attention as it is shows AAI of 1.57 along with insurance premia of 6.7% and 6.2%, depending on the distribution. Klaipėda county exhibits both high specialisation in mixed cereals (AAI of 1.26) and insurance premiums of 8.3% and 7.6% according to the normal and the logistic distributions, respectively. Panevėžys county is also related to excessive production risk (insurance premia of 7.6% and 5.3%) considering its value of AAI (1.13). Finally, Tauragė county shows extreme production risk (7.7% independently of the distribution assumed) along with AAI of 1.23. However, the risk is directly related to AAI for potatoes in general.

Therefore, the estimates of the productions risk can be employed to identify the most critical areas and crops in terms of risk-specialisation framework. Further research, however, is needed to identify the most appropriate measures in each case. In general, insurance subsidies along with adjustment in varieties can be given as the key measures for management of production risks.

4. THE EFFECTS OF PRODUCTION AND PRICE RISKS ON REVENUE

As it was demonstrated in the preceding sections, multiple factors affected the change in crop revenue in Lithuania during 2000-2015. In order to attribute the change in the crop revenue to particular factors, we proposed an LMDI-based IDA model in Section 1.4. This section applies the model to quantify the underlying factors in both multiplicative and additive manners. As it was demonstrated in Section 2.4, the crop revenue had been rather stable until year 2007. Therefore, we also pay a particular focus on the periods of 2000-2006 and 2006-2015 to capture the effects associated with accession to the EU, besides other circumstances.

4.1. Additive decomposition

The additive decomposition allows factorizing the absolute changes in the crop revenue. Following Eq. 25, the total change in the crop revenue over 2000-2015 (i.e., some 813 million EUR) is attributed to the seven factors. The two sub-periods of 2000-2006 and 2006-2015 are considered. The following Table 27 presents the results.

Table 27. Absolute decomposition of changes in the crop revenue (million EUR), 2000-2015

Effect	2000-2006	2006-2015	2000-2015
ΔR_A **– area sown**	6.6	282.4	289.0
ΔR_S **– spatial distribution**	3.8	-8.3	-4.5
ΔR_M **– crop mix**	-48.0	78.9	30.8
ΔR_{Y^*} **– yield trend**	-22.3	411.1	388.8
ΔR_Y **– deviation from yield trend**	-149.0	201.3	52.2
ΔR_{P*} **– price trend**	98.6	86.2	184.8
ΔR_P **– deviation from price trend**	23.3	-150.9	-127.7
Total	**-87.1**	**900.5**	**813.5**

As one can note, the magnitude of the change in the crop revenue for 2000-2006 is some ten times lower if opposed to that for 2006-2016. The directions are different as the former period shows a decrease, whereas the latter one – an increase in the crop revenue. The two sub-periods are also different in terms of the driving forces of the revenue change.

For the sub-period of 2000-2006, deviation from the yield trend played the most important role by inducing a decrease in the revenue of some 149 million EUR. Along with negative yield trend, this indicates that farming practices had been deteriorating during the said period. The price trend was going up and contributed to increase in the revenue of some 99 million EUR. Furthermore, deviations from the trend rendered an additional increase of over 23 million EUR. Therefore, both stronger integration into the global markets and favourable situation there contributed to the growth in revenue. The changes in crop mix also played an important role and caused a decrease in the revenue of some 48 million EUR. This is mainly due to shift from potato towards rape growing. Indeed, country-wide shifts in crop mix are likely to cause loss in productivity due to adjustment costs. The changes in area sown and spatial distribution thereof pushed the revenue up by some 10 million EUR altogether.

Sub-period of 2006-2015 features a significant impact of the yield trend. Specifically, the contribution of the latter factor amounted to some 411 million EUR. Deviations from the yield trend were also mostly positive and further increased the revenue by over 201 million EUR. Obviously, the support payments under the EU policies enabled farmers to apply more inputs (fertilizers, pesticides), improve machinery thereby boosting yield rates. The price trend showed a positive contribution of 86 million EUR, yet it was offset by the negative effect of the deviations from the price trend of -151 million EUR. Comparing with the previous sub-period, the effect of the price trend has decreased, possibly due to higher convergence with international prices. On the other hand, price volatility has played a more important role. An increase in the area sown (Fig. 1) resulted in growth in the revenue of over 280 million EUR. This is also an outcome of the support payments under the CAP.

The period of 2000-2015 marks an increase in the total crop revenue which had been mainly achieved during 2006-2015. Both intensive and extensive developments took place during the research period. An increase in the yields might slowdown the increase in prices of some crops if their markets became saturated. We will further analyse these changes in a more detailed manner.

In order to depict the underlying trends in each factor of the crop revenue, Fig. 10 presents the dynamics of these throughout 2000-2015. The major force that has been driving the crop revenue up, i.e. yield trend, shows an increasing magnitude for the period of 2010-2015. This implies that increase in crop yields is likely to systematically continue during the immediate future periods. The area sown effect shows a steady contribution towards the increase in the crop revenue for 2011-2015, whereas less significant contributions are usually observed for the earlier years. This can be explained by a decreasing profitability of animal farming (dairying), which caused an increase in the amount of the arable land. The last two periods of 2013-2015 sow a decreasing price trend and a corresponding negative impact on the crop revenue. The deviations from trend have shown a cyclical pattern since 2006. This indicates that price risk might be an important factor for farm income and appropriate measures could be foreseen in support policy schemes (e.g., Rural Development Programme). The negative deviations from the price trend during 2013-2014 can be attributed to improving supply of the main crops in the world and subsequent reduction in prices. Indeed, further decomposition is needed to identify the crops and/or regions mostly affected by these factors.

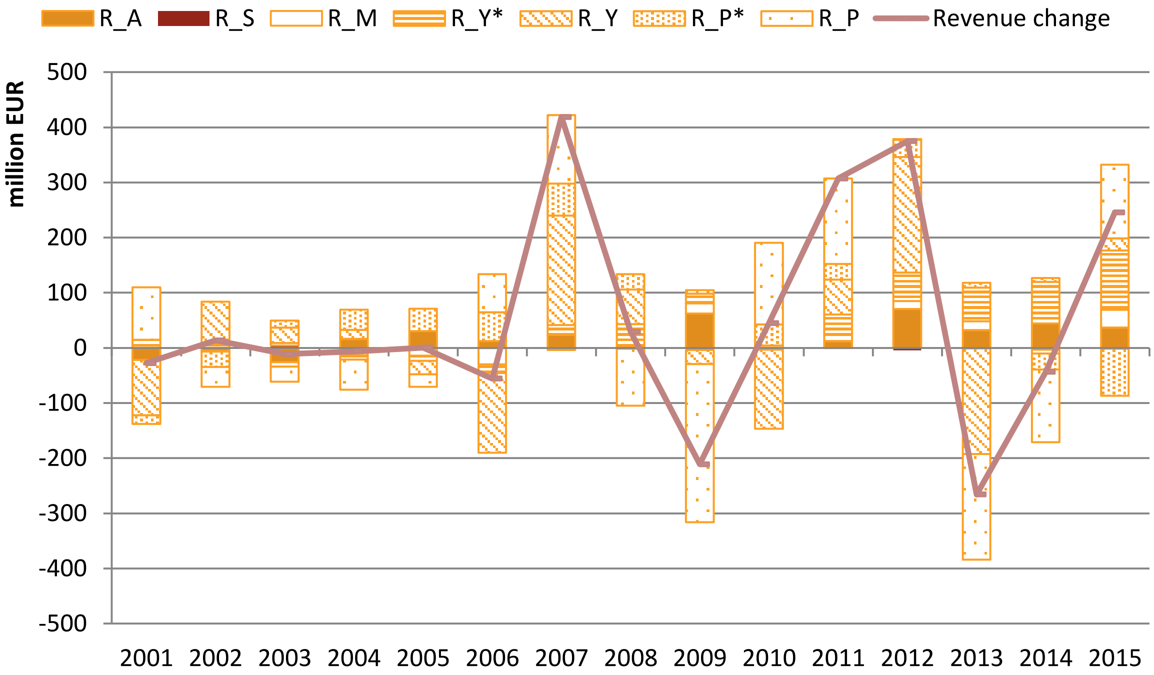


Fig. 10. Chain-liked additive decomposition of the crop revenue, 2000-2015

Note: the current periods are given on the x-axis.

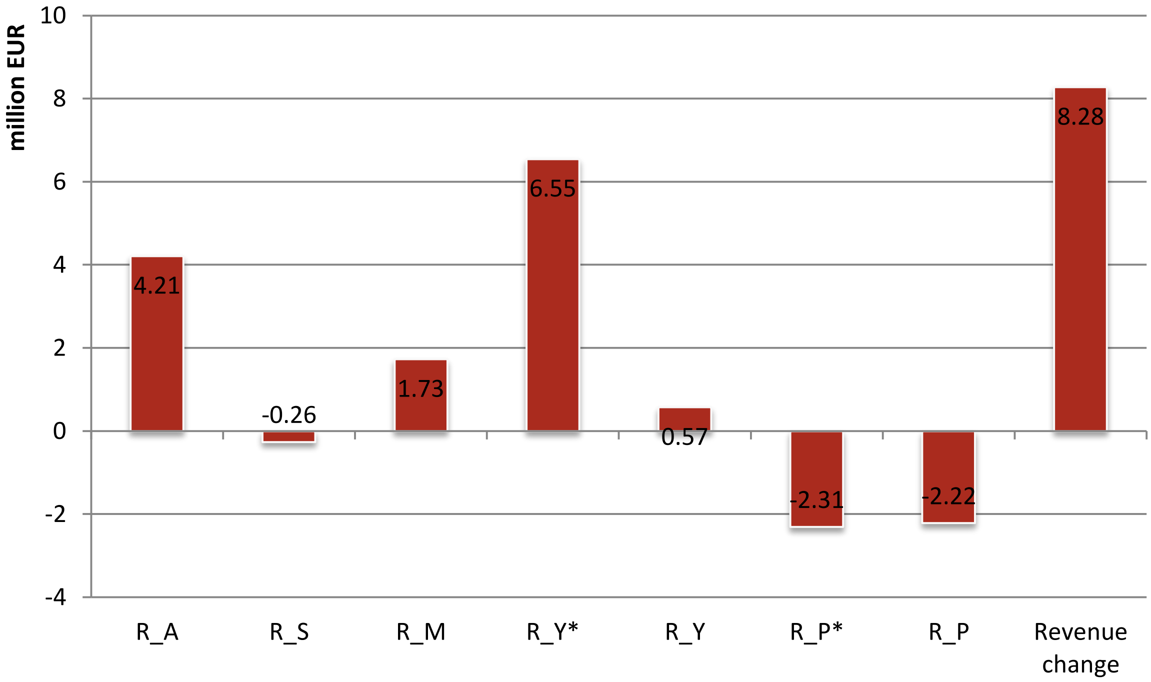


Fig. 11. Decomposition of the average annual change in crop revenue based on the stochastic trend

We further apply the linear trend for each component of the crop revenue at the aggregate level (Fig. 10). By doing so, we obtain the "average" annual change in each component of the crop revenue and account for statistical noise. Similar data are available in Table 27, yet the trend-based estimated allow for a kind of forecasting assuming the same directions in change of certain effects will prevail in the future. Fig. 11 presents the results. As one can note, the yield trend is the dominating effect inducing the average change of some 6.55 million EUR per year. Area expansion effect is the second highest and accounts for the growth of 4.21 million EUR. Even though the cumulative effect for price trend was positive during 2000-2015 (Table 27), the linear trend suggests a decrease in crop revenue due to both price trend and deviations from trend. These findings reflect the recent trends in in international markets associated with decreasing prices of grain and other crops.

The additive decomposition is useful to define the contributions of different factor sin absolute terms. However, crop- or region-wise comparisons might be more meaningful in relative terms. Therefore, the following sub-section proceeds with the multiplicative decomposition.

4.2. Multiplicative decomposition

The additive decomposition is useful in identifying the magnitudes of the effects associated with different factors. The absolute measures, though, are less useful in case of comparison across different dimensions of the IDA model. This section, therefore, presents the multiplicative decomposition at different aggregation levels.

The aggregate chain-linked analysis is presented in Table 28. Note that the figures given in the table are logged growth rates rather than factors of growth. Therefore, the change in crop revenue from some 441.0 million EUR in 2000 up to over 1254 million EUR in 2015 (cf. Table 6) corresponds to the factor of growth of 2.845, which, in turn, translates to the logged rate of growth of 104.5% (ca. 7% p.a.). Note that the importance of some factors in the multiplicative setting is different from those in the additive setting due to differences in the weighting scheme. For instance, the additive decomposition suggested the price trend and the deviations from the price trend as having equal magnitudes, yet the multiplicative decomposition suggests deviations from the price trend being a factor of minor importance. Specifically, the additive decomposition suggests that the relative impact of the deviations from the price trend played no significant role, whereas that of the price trend became even more important. The area effect along with the yield trend effect remained important factors behind the change in the crop revenue. Specifically, the changes in the price trend, the yield trend, and the area sown caused increases in the crop revenue of 44%, 37%, and 34%, respectively, during 2000-2015 (the logged rates of growth).

Table 28. Multiplicative decomposition of changes in the crop revenue, 2000-2015 (%)

Period	D_A	D_S	D_M	D_{Y*}	D_Y	D_{P*}	D_P	$D = R_T / R_0$
2001	-5.0	0.1	0.0	3.3	-23.6	-3.7	22.3	-6.5
2002	-1.3	0.0	-0.3	1.9	18.2	-6.5	-8.7	3.2
2003	-6.2	1.1	1.1	-1.8	6.7	3.0	-6.6	-2.7
2004	3.9	0.2	-2.3	-2.8	3.8	8.9	-13.2	-1.5
2005	7.5	-0.3	-3.2	-2.2	-5.9	9.8	-5.6	0.2
2006	3.3	-0.1	-7.7	-4.2	-37.8	13.7	18.2	-14.7
2007	4.5	0.1	-0.7	3.2	37.0	10.8	23.2	78.1
2008	-0.2	0.4	0.1	5.0	7.9	3.6	-13.1	3.7
2009	9.1	-0.5	2.7	2.5	-3.7	0.9	-41.5	-30.5
2010	0.0	0.1	-0.5	0.6	-23.4	6.2	24.2	7.3
2011	1.5	0.1	1.4	4.7	8.1	3.6	19.9	39.4
2012	6.3	-0.4	1.3	4.6	18.7	2.8	0.1	33.5
2013	2.8	-0.1	1.3	5.2	-16.2	0.8	-16.2	-22.5
2014	4.3	-0.3	-0.7	7.3	0.7	-2.8	-12.8	-4.2
2015	3.3	-0.1	2.8	9.5	1.9	-7.5	11.9	21.8
2000-2015	33.8	0.2	-4.5	37.0	-7.7	43.7	2.1	104.5
2000-2006	2.2	0.9	-12.3	-5.9	-38.7	25.2	6.5	-22.0
2006-2015	31.6	-0.7	7.8	42.8	31.0	18.5	-4.4	126.5

Note: the current periods are given in the first column; logged rates of growth are given.

As the multiplicative decomposition is based on relative numbers (i.e., rates of growth), it is more appealing in terms of comparisons of different dimensions of the IDA model. Therefore, Fig. 12 presents the multiplicative decomposition of the crop revenue for the two sub-periods, namely 2000-2006 and 2006-2015. Note that the logged growth rates for the two periods are -22% and 127%, respectively (cf. Table 28). Fig. 12 shows that the effects of spatial distribution, price trend and deviations from price trend were rather similar across the two sub-periods in relative terms. However, the latter effect showed different directions across the two sub-periods, yet it did not depart far from the zero value.

The effect of the area sown played a much more important role in the second sub-period of 2006-2015. Specifically, the effect of just 2% increased up to 32% in the second sub-period. The key reason for such a change is a reinvigoration of farming activities due to CAP payments. The effects of the CAP payments on farming activities in Lithuania has been analysed by Latruffe et al. (2010). They concluded that farmers have become more certain about the future of their businesses due to the payments and, therefore, opted for increasing the scale of operation.

The crop-mix effect had a negative impact (-12%) upon crop revenue in 2000-2006. This might be related to livestock farming which required input of less profitable crops. The next sub-period saw an increase in the revenue due to adjustments in the crop-mix of some 8%. The increasing importance of cash crops (e.g., winter rape, winter wheat) obviously has fuelled these changes. However, the adjustments in the second sub-period did not offset the negative effect of the first one.

The effects of yield trend and deviations from the trend also show significant differences across the two sub-periods. During 2000-2006, the yield trend was slightly negative as indicated by the associated effect of -3%, while deviations from the yield trend had even more suppressing effect of 39%. The deviations from the yield trend were caused by droughts in several years. The negative yield trend can be attributed to insufficient and/or inappropriate application of agrochemicals. The situation has changed afterwards and the sub-period of 2006-2015 indicates positive contributions of both yield trend and deviations from it. Specifically, the yield trend caused an increase in the crop revenue of some 43%, whereas deviations from the yield pushed the revenue up by another 31%. Suchlike development in the second sub-period can be explained in terms of increased access to inputs due to the CAP payments as well as climate change. Indeed, Povilaitis et al. (2013) noticed that the average temperature has increased in Lithuania (e.g. 2-3°C in 2010-2011 if compared to the average value for the period of 1961-1990). Therefore, yield risk is likely to be reduced in Lithuania.

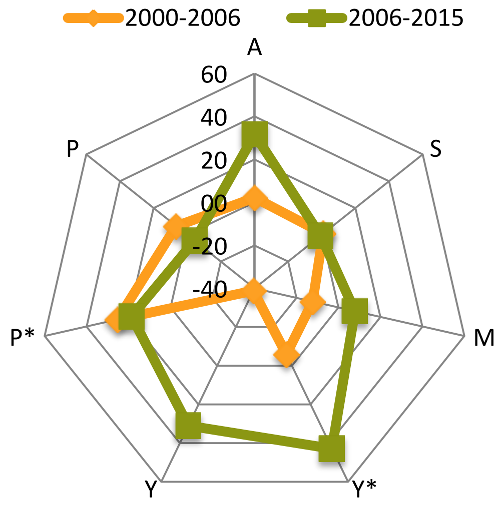


Fig. 12. The multiplicative decomposition of the crop revenue for the sub-periods of 2000-2006 and 2006-2015

Even though the price trend exerted similar effect upon the crop revenue during the two sub-periods, the situation regarding deviations from the trend is somewhat different. Specifically, the effect of 7% was observed for the period of 2000-2006 and -4% for 2006-2015. As lower demand and high inventories have been specific to the international markets (OECD, FAO, 2016), the price risk is likely to persist in the future. However, short-run price fluctuations have had relatively low impact upon crop revenue in Lithuania if looking at the cumulative effects.

The crop-wise decomposition of changes in the crop revenue is presented in Table 29. The area effect (D_A) shows the impact of expansion in the area sown with crop-mix held fixed. As winter wheat constitutes the major crop in terms of the share of the area sown, it shows the highest contribution to change in the crop revenue due to the area effect. The spatial distribution effect (D_S) implies that changes in the distribution of area sown across the counties had a positive impact from the viewpoint of spring barley and winter wheat as these crops were prevalent in counties experiencing an increase in their relative importance. In the crop-wise decomposition, the crop-mix effect (D_M) simply indicates the increase in crop revenue due to changes in the prevalence of a certain crop. The increasing shares of winter wheat and winter rape contributed to increase in the crop revenue by 13.6% and 11.3%, respectively (other effects remaining fixed). The major sources of decrease in the crop revenue were spring barley and potatoes, which were associated with contractions by 13.1% and 29.7%, respectively. The deviations from the yield trend (D_Y) are associated with the yield risk. Indeed, the lowest contributions to the crop revenue were observed for potatoes (-5.3%), winter wheat (-2.1%), and winter rape (-2%).

Table 29. Crop-wise decomposition of changes in crop revenue, 2000-2015

Crop	D_A	D_S	D_M	D_{Y*}	D_Y	D_{P*}	D_P	$D = R_T / R_0$
Winter wheat	10.1	1.0	13.6	14.3	-2.1	6.3	-4.6	38.6
Winter triticale	1.6	-0.1	2.7	1.3	-0.4	1.5	-1.4	5.3
Winter rye	0.5	-0.1	-4.5	0.3	0.1	0.3	-0.3	-3.8
Winter barley	0.2	0.0	0.4	0.2	-0.2	0.2	-0.3	0.5
Spring wheat	3.9	0.1	8.8	6.2	0.4	1.3	1.6	22.2
Spring barley	5.0	0.7	-13.1	7.0	1.0	5.9	-0.1	6.5
Spring triticale	0.2	0.0	0.0	0.4	-0.1	0.0	0.0	0.5
Oats	0.7	-0.1	0.3	0.6	0.3	0.7	-0.2	2.3
Buckwheat	0.3	0.0	0.5	0.2	0.0	0.2	0.3	1.5
Mixed cereals	0.2	0.0	-0.1	0.2	0.1	0.3	0.3	1.0
Maize	0.4	0.0	1.1	0.3	-0.2	-0.1	-0.1	1.4
Legumes	0.7	0.1	4.9	1.5	-0.3	0.4	0.0	7.2
Winter rape	2.7	-0.1	11.3	3.2	-2.0	2.4	-1.6	15.8
Spring rape	3.4	0.2	-0.8	2.8	0.8	4.6	1.4	12.4
Potatoes	4.1	-1.4	-29.7	-1.5	-5.3	19.8	7.0	-6.9

The price trend was positive for all the crops save spring triticale and maize. Winter wheat, spring barley, and spring rape constitute the major crops accounting for increase in the crop revenue due to the price trend (the logged rates of growth of 6.3%, 5.9%, and 4.6%, respectively). The cumulative effects for deviations from the price trend indicate price risk the results in Table 29 suggest that most of the crops showed negative effects associated with the deviations from the price trend. However, potatoes showed a positive effect of 7%.

The projections of yield trends (Supit et al., 2012; Povilaitis et al., 2013) indicate that increasing yields are expected in Lithuania for the next several decades (at least). This is the direct outcome of the climate change manifested by higher temperatures. In order to exploit these changes introduction of new crop varieties might be needed. For instance, Povilaitis et al. (2013) noted that medium-season maize varieties will be more preferred.

The decomposition of the crop revenue at the regional level is presented in Table 30. As one can note, the four counties, namely, Šiauliai, Kaunas, Panevėžys and Marijampolė counties, accounted for increase in crop revenue by 85.5%, whereas the other counties accounted for increase of 19%. Out of the former four counties only Marijampolė county showed a negative structural effect of -0.5%. Therefore, the expansion of the area sown in the latter county did not keep the same pace as that in the other expanding counties. Obviously, Marijampolė county exhibits the lowest amount of grassland as it is the most fertile region in Lithuania.

Table 30. Region-wise decomposition of changes in crop revenue, 2000-2015

	Alytus	Kaunas	Klaipėda	Marijampolė	Panevėžys	Šiauliai	Tauragė	Telšiai	Utena	Vilnius
D_A	1.1	6.4	1.3	5.0	5.7	8.8	1.4	1.3	1.0	1.8
D_S	-0.8	1.4	-0.9	-0.5	1.7	1.9	-1.8	0.8	-0.8	-0.7
D_M	-1.4	-0.3	-1.7	0.7	0.5	2.5	-0.9	-0.9	-0.9	-1.9
D_{Y*}	0.5	8.8	1.0	5.4	5.6	9.7	1.5	1.1	1.6	1.7
D_Y	-0.1	-1.9	-1.4	-2.3	0.3	-1.3	-0.9	0.0	-0.3	0.3
D_{P*}	2.0	7.4	2.7	5.6	6.2	10.1	2.6	2.2	1.6	3.3
D_P	0.2	-0.2	1.0	0.6	-1.1	-1.0	0.6	0.6	0.4	0.9
$D = R_T / R_0$	1.5	21.5	1.9	14.4	18.8	30.8	2.5	5.1	2.6	5.4

The four most important counties show the same factors that explain the largest share of changes in crop revenue there. These are area, yield trend, price trend effects. Not that the effect of deviations from the yield trend is negative for the latter counties (or slightly positive for Panevėžys county). Therefore, yield risk remains important for these counties. However, the yield risk (as captured through the effect of deviations from the yield trend) is rather important in Klaipėda and Tauragė counties, where the corresponding effects are relatively high if compared to the overall contributions of those counties. The four major counties also show negative effect of deviations from the price trend (Marijampolė county shows slightly positive effect). Therefore, the prevalence of cash crops in the major counties is associated with increasing price risk there.

The application of IDA at different dimensions of aggregation enabled to identify the differences in the factors behind changes in the crop revenue across periods, crops, and regions. It can also be seen that different regions face different effects of multiple factors. Therefore, advisory services and support measures can be adjusted in order to meet region-specific problematique. It is evident that certain regions are specific with higher levels of price risk, whereas yield risk prevails everywhere, yet its relative importance is not uniform. Crop insurance, support schemes, and diversification should be applied systematically in order to cope with the enumerated risks.

CONCLUSIONS

This study aimed to quantify yield and price risks in Lithuanian agriculture. First, the trends in area sown, crop yields, and regional advantage were analysed by considering various indicators. Second, production risk was estimated by means of statistical distributions. Third, the index decomposition analysis was employed to assess the impacts of price and yield risks on crop revenue in Lithuania. The analysis focused on the following crops: wheat, triticale, rye, barley, oats, buckwheat, mixed cereals, maize, legumes, rape and potatoes.

The period of 2000-2015 marked significant changes in terms of both cropping patterns and extent in Lithuania. The most evident trend is the increase in area sown from 1.2 million ha in 2000 up to 1.7 million ha in 2015. Such developments undoubtedly contributed to increase in crop revenue in Lithuania. The major factor causing the increase in area sown is Lithuania's accession to the EU in 2004. This allowed to achieve higher convergence with the international markets and provided stimuli for expansion of farming (most importantly, by means of the income support).

Application of the Herfindahl-Hirschman index suggested that Lithuanian counties increased the diversity of crop-mixes during 2000-2010, whereas the specialisation increased afterwards and exceeded the level of 2000 in 2015 in many counties. Such a trend, in general, implies an increasing risk. A deeper analysis suggests that winter wheat, legumes, and winter rape exhibited the highest increases in the shares of their areas sown. On the contrary, winter rye, spring barley, and potatoes followed the decreasing trends. As an outcome, the estimated crop revenue rose from some 441 million EUR in 2000 up to 1254 million EUR in 2015.

Production risk was estimated by means of normal and logistic distributions. In addition, linear moving average technique was applied in order to smooth the time series. The highest probabilities of yield loss were observed for maize, winter barley, and spring triticale. These crops require introduction of improved varieties in order to weather the Lithuanian climate. However, the probability of yield loss does not take into account the extent of loss. The relative insurance premia were estimated for each crop in order to quantify the production risks. The results indicate that maize, buckwheat, winter barley, and winter rape show the highest production risk as represented by the relative insurance premia. The spatial differences in insurance premia were also observed. Indeed, maize showed the highest spatial variation in insurance premia, whereas the lowest variation was observed for oats. The comparison of the aggregate advantage index and insurance premia across the counties showed that the inverse relationship between the latter two variables existed for most of the crops. Potatoes and spring triticale can be given as the contrasting examples, i.e. counties with higher production risk exhibit higher shares of areas sown under respective crops.

Index decomposition analysis was facilitated by the Mean Logarithmic Divisia Index. The linear moving averages were also employed in order to discriminate long-term developments and short-term fluctuations in yields and prices. The results suggested that the effects of the area sown, the yield trend, and the price trend were the most important in driving the crop revenue up during 2000-2015. However, different patterns can be observed for the sub-periods of 2000-2006 and 2006-2015. Obviously, the first sub-period corresponds to the pre-accession to the EU (as well as some additional years, possibly to adjustment processes), while the second one spans over the years when the Common Agricultural Policy has been becoming more important in shaping the activities of the agricultural sector. As regards the changes in the crop revenue, the first sub-period indicated a decrease of some 87 million EUR, whereas the second one – and increase of some 814 million EUR. The price trend remained a positive factor contributing to the change in the crop revenue, whereas the effects of area sown and yield trend became positive only in the sub-period of 2006-2015. The increasing yield trend can be explained by both climate change and increased use of agrochemicals due to support payments. Crop-wise analysis implied that winter wheat, spring wheat, winter rape, and spring rape offered the most important contributions the change in the total crop revenue. Region-wise analysis also enabled to identify regions that were most important in driving the total crop revenue up.

The carried out analysis can be beneficial in adjusting famers' decisions through advisory services and public support. Specifically, incentives and support for crop insurance can be adjusted across the regions (and crops) in order to tackle the most problematic issues. Different risk measures can also be used as criteria for definition of less favoured areas. As regards the research methodology, further improvements can be made into different directions. First, the data set can be improved in order to reflect the selling prices more accurately. Second, different statistical distributions can be applied to improve the accuracy of the modelling of the insurance premia. Third, the index decomposition analysis can consider different factors and decomposition principles.

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