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Production risk in the crop farming of the Baltic States, Poland, and Germany

Martynas Zegunis
Faculty of Economics and Business Administration, Vilnius University,
Lithuania
martisz755@gmail.com

Tomas Balezentis
Faculty of Economics and Business Administration, Vilnius University,
Lithuania
tomas.balezentis@evaf.vu.lt
ORCID 0000-0002-3906-1711

Abstract. Increasing climate volatility has called for further analysis of the risk management measures in agriculture. This paper sheds more light on production risks in the crop farming of northeastern European agriculture. Specifically, the cases of the three Baltic States (Estonia, Latvia, and Lithuania) are juxtaposed to those of Poland and Germany. Thus, both economically developed and developing economies are considered in the analysis. The study covers major crops throughout 2004-2022, i.e., considers the post-accession period of the new EU member states. The research relies on the downward coefficients of variation as the hazard measures. The conditional means were obtained by applying the moving average approach. The results suggest that the highest yield risk is observed for wheat and rape, whereas barley stands at the other end of the spectrum. Regarding the country-wise comparison, risk measures were highest in Estonia and lowest for Poland and Germany.

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1. INTRODUCTION

The agricultural sector has been subject to numerous risks throughout history. However, the recent trends of climate change have called for increased attention towards the effects and management of the climate-related risks that are especially harmful to crop farming (Zafeiriou et al., 2022). The need to devise adaptation measures has become evident in order to cope with the merging risks associated with agribusiness

(Anderson et al., 2020). Such measures include both agronomical development actions and economic measures. Climate-smart agriculture has emerged as a response to the climate threats (Zhao et al., 2023). The knowledge of risk may also supplement the existing measures of agricultural sustainability (Kulyakwave, Wen & Shiwei, 2023; Wang et al., 2022).

Appropriate management of the adaptation strategies requires proper measurement of the agricultural risk. Various measures and methodologies have been developed to address the yield and price risk in agriculture (Just and Pope, 2003). Indeed, the agricultural sector may diversify its activities in the sense of only livestock or crop farming, as well as mixing crop and livestock. Therefore, it is important to assess the risks associated with certain types of agricultural products akin to Finger (2010) and Leng and Hall (2019), who analysed the yield variability in different contexts.

The issue of agricultural risk has been acknowledged globally. In the EU, one of the largest agricultural producers in the world, the risk management measures are mostly related to promotion of agricultural insurance (Tangerman, 2011; Ecorys and Wageningen Economic Research, 2017). However, researchers have also made further proposals for adopting measures to reduce losses in agricultural revenues (van Asseldonk et al., 2019; Eidukaitis & Balezentis, 2022). The measures of agricultural insurance are supported at the national level and vary across the EU Member States. Thus, country-based analysis is needed.

This paper embarks on the analysis of production (yield) risk in the selected central and eastern European countries. These countries include the Baltic States (Estonia, Lativa, and Lithuania), Poland, and Germany. This makes it possible to compare the trends in the agricultural risk within a region with similar climatic conditions yet with different farm structure and level of intensity of the agricultural practices (e.g., different levels of intermediate consumption intensity). The analysis relies on the calculation of the downside standard deviation and risk measures based on the multi-annual trend obtained through moving average analysis. This allows us to take into account the developments in the trends that are relevant for such countries as the Baltic States where new farm structures and support policies have been introduced since the accession to the EU. Similarly, the energy sector was affected by novel policies and contexts (Streimikiene & Mikalauskiene, 2022; Streimikiene, 2023). The study considers the yield risk measures for barley, oats, rapes, wheat, and rye.

2. LITERATURE REVIEW

Risk analysis has been an important topic for economic research (Ma, Ji, 2023). Agriculture, often characterized as a high-risk sector, poses unique challenges for producers due to its inherent unpredictability. The success of agricultural endeavors is notoriously difficult to forecast, primarily because farming operations are conducted in open environments, leaving them highly susceptible to the caprices of weather patterns, climate fluctuations, and other environmental factors (Machova et al., 2022; Shar, Jiskani & Qi, 2021; Zsarnóczai et al., 2021). This reliance on natural elements renders agricultural production inherently uncertain and exposes producers to a myriad of risks.

One of the primary risks faced by agricultural producers pertains to production, specifically the variability in yields. Factors such as adverse weather conditions, pest infestations, diseases, and soil quality can significantly impact crop yields, leading to fluctuations in production output. This variability introduces uncertainty into the farming process, making it challenging for producers to accurately predict and plan for their agricultural activities.

In addition to production risks, agricultural producers also contend with price risks. The inelasticity of the supply of agricultural products in response to changes in market prices exacerbates this risk. Even minor fluctuations in demand or market conditions can lead to significant price volatility, affecting the profitability and financial stability of agricultural operations. Furthermore, changes in market conditions and government policies can further influence prices, adding another layer of complexity to price risk management for producers (Dykha et al., 2021; Eidukaitis & Balezentis, 2022; Kurniawati, Werdani & Mege, 2020).

Production, financial, personal, institutional, and market risks are identified by Komarek et al. (2020). The latter study also showed that most of the studies dealing with agricultural risk focus on production risk. Their significance increased during the pandemic challenges (Mishchuk et al., 2023; Olasanmi et al., 2023).

Finger et al. (2023) analysed the risk attitudes of Swiss farmers via the repeated measurements that involves self-assessment exercises. The latter study identified agricultural, marketing, external financing, and production risks. It was found that farmers' risk aversion may be highly time-variant and subject to external shocks.

Indeed, the prices and yields are often negatively correlated which implies that time periods that are unfavourable in the sense of yields may be favourable in the sense of prices (Ahmed, Serra, 2016). Accordingly, insurance policies based on the revenue flows tend to be cheaper than those based on the yield risk only. However, measurement of the revenue is more complicated than that of the yields. In this regard, research of financial issues in agriculture are closely related to investigations of investments risks (Machova et al., 2022) as well as the studies of external factors of instability of agriculture outcomes (Vasylieva & James, 2021; Lehenchuk et al., 2023).

Iyer et al. (2020) presented a review of studies on the risk analysis in European agriculture. The synthesis of the literature suggested that there have been several types of methods applied for the analysis of risk. The primary data (e.g., experiments and ad-hoc surveys) can be based on the scales or choice tasks. The secondary data can be analysed by econometric or mathematical methods.

Boysen et al. (2023) used the computable general equilibrium model to assess the impact of agricultural insurance measures triggered by prices, revenue, or income. Severini et al. (2019) used the micro-simulation approach to estimate the effects of mutual funds on the income of the Italian farms. Simbürger et al. (2022) applied the simulation approach to assess the potential impact of the provision scheme (as an alternative to agricultural insurance). The results indicated that the adoption and effectiveness of the provision scheme is highly related to the prevailing tax system.

The literature review implies that production risk remains an important issue in European agriculture (as well as globally). The research on agricultural risk mostly deals with the developed economies. Therefore, there is still a need to address the issues of agricultural risk (and its management) in the Central and Eastern European countries that face substantial structural changes.

3. METHODOLOGY

The production risk is analysed by using the country-level data from the FAOSTAT database for 2004-2022. This period corresponds to the expansion of the EU that rendered implementation of the Common Agricultural Policy (CAP) in the Baltic States and Poland. This section further discusses the quantitative approach used for calculating the measures of yield risk for the selected crops (wheat, maize,

Following Zhang and Wang (2010), we use the moving average approach to estimate the expected yield (for a certain crop, country, and year combination). This approach allows for non-linearities that may be present in the course of the adjustment to requirements of (the newly imposed) CAP support measures. For year *t*, the yield is estimated as the order-four moving average:

$$\hat{y}(t) = \frac{y_{t-3}+y_{t-2}+y_{t-1}+y_t}{4}. \tag{1}$$

An important measure of risk is coefficient of variation (relative standard deviation). It compares the standard deviation of the yield, s_y, to the average yield, $\bar{y}$, for a certain crop and country combination:

$$CV_y = \frac{s_y}{\bar{y}} . \tag{2}$$

The standard deviation is obtained as

$$s_y = \left(\frac{1}{n-1} \sum_{t=1}^{T} \left(y(t) - \bar{y} \right)^2 \right)^{1/2} . \tag{3}$$

For risk analysis, it is also important to measure the deviations from the expected value that are negative. This is done to avoid the effect of desirable upturns in the yields. The downside risk measures can be used for this aim. The downside coefficient of variation is defined as:

$$CV_y = \frac{s_y^d}{E\left(y(t)\right)} . \tag{4}$$

The expected value of yield is defined as the average estimate of the yield over the time period covered. In this case, the downside standard deviation is used:

$$s_y^d = \left(\frac{1}{n-1} \sum_{t=1}^{T} \min\left\{ \left(y(t) - \hat{y}(t) \right), 0 \right\}^2 \right)^{1/2} . \tag{5}$$

Relative deviation from the expected yield can be used as the hazard level:

$$h(t) = \frac{y(t) - \hat{y}(t)}{\hat{y}(t)} . \tag{6}$$

Risk is measured as the product of hazard and the corresponding probability level. In lines with Zhang and Wang (2010), one can denote the coverage level as $\lambda \in (0,1)$. Then, the yield risk can be measured as a product of the conditional hazard and probability of hazard that falls below the coverage level:

$$R(t) = \left(h(t) \mid \hat{y}(t) < \lambda y(t) \right) P\left(\hat{y}(t) < \lambda y(t) \right) . \tag{7}$$

We use the moving average for the first available time period to fill the gap for the previous three years to avoid data loss. The measures of yield variability and risk are calculated for each crop and country combination. Note that risk and downward measures refer to the moving average whereas other measures are defined relative to the sample mean.

4. RESULTS

The study focuses on the production risk associated with wheat, rapeseed, rye, barley, and oat farming in the selected countries. The dynamics in areas sown under these crops across the countries considered are shown in Fig. 1. As one can note, the three Baltic States showed the highest growth in the areas sown under the aforementioned crops. The growth ranged from 45% for Estonia to 97% for Latvia. For Poland and Germany, are sown under these crops declined by 10% and 11% respectively. However, the latter two countries have much more importance in the cereal markets given their production volume (and land area). A steep increase in the land area sown under the cereal crops and oilseeds observed in the Baltic States can be related to vast amounts of previously abandoned land that were used for wheat and rapeseed production.

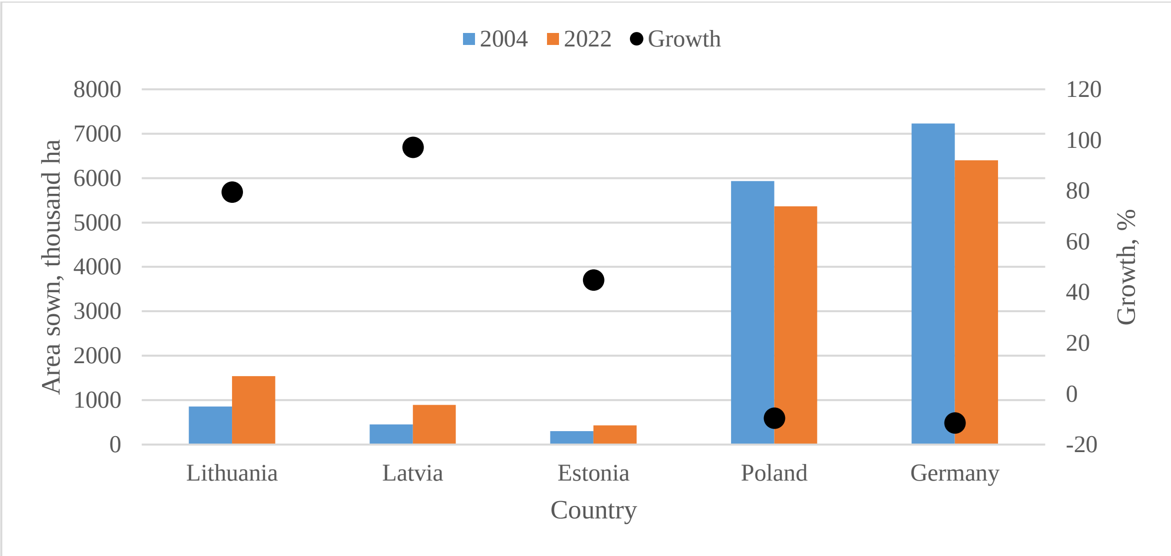

Figure 1. Country-wise dynamics in the areas sown under wheat, rapeseed, rye, barley, and oat in the selected countries, 2004 and 2022

Source: designed by the authors.

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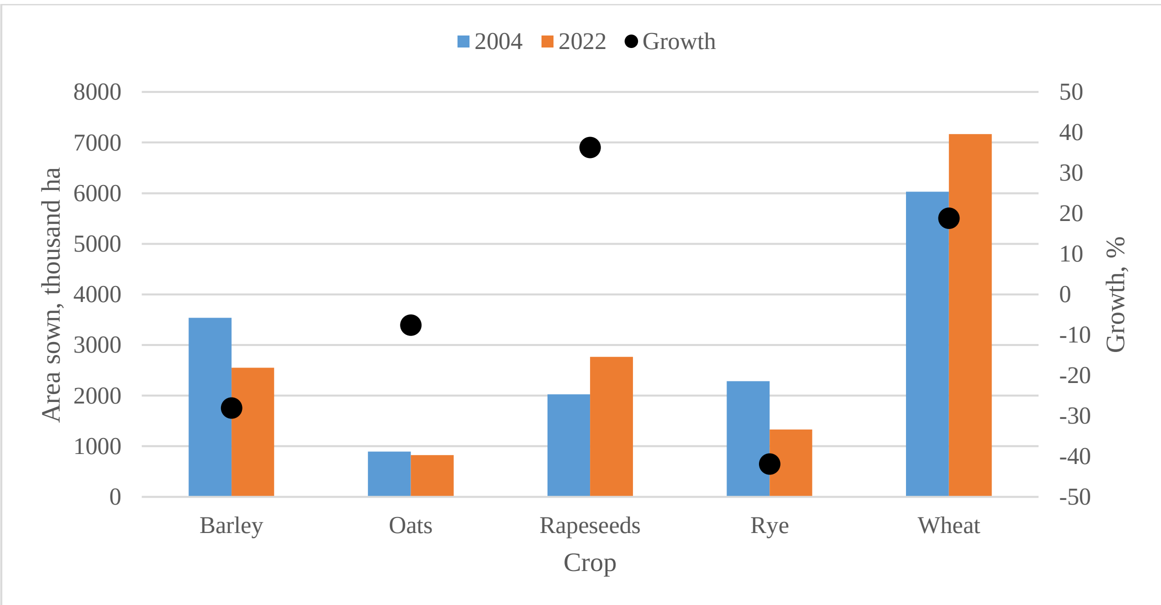

Figure 2. Crop-wise dynamics in the areas sown under wheat, rapeseed, rye, barley, and oat in the selected countries, 2004 and 2022

Source: designed by the authors.

It was wheat and rapeseed that showed the steepest increase in their areas sown in the selected countries with growth of 19% and 36% respectively (Fig. 2). Lithuania and Latvia triples there are sown under rapeseed during 2004-2022. The other three crops posted a decline in their areas. The steepest decline was observed for rye (-42%) which can be attributed to changes in the market demand and climate change which is particularly challenging for winter crops.

The average yields of the selected crops for the period of 2004-2022 are shown in Fig. 3. The highest yields are (systematically) observed in Germany and Poland. The only exception is that of rye – in this case, Poland shows a mediocre yield (Germany maintains the highest yield anyway). The differences in the yields can be attributed to numerous internal and external factors, including the intensity of the use of agrochemicals, climatic conditions, and soil.

The dynamics in the yields are shown in Fig. 4. It can be noted that the latter figure shows patterns that are opposite to those depicted in Fig. 3. Specifically, the Baltic States (and Poland) showed lower yield compared to the case of Germany for all crops, yet the growth rates are higher for the low-yield countries. This implies that a certain type of convergence has been taking place. The increasing use of agrochemicals, application of advanced agricultural practices, and use of improved crop varieties have led to declining yield gap. The yields for Germany (oats, rapeseed, and wheat) showed a decline.

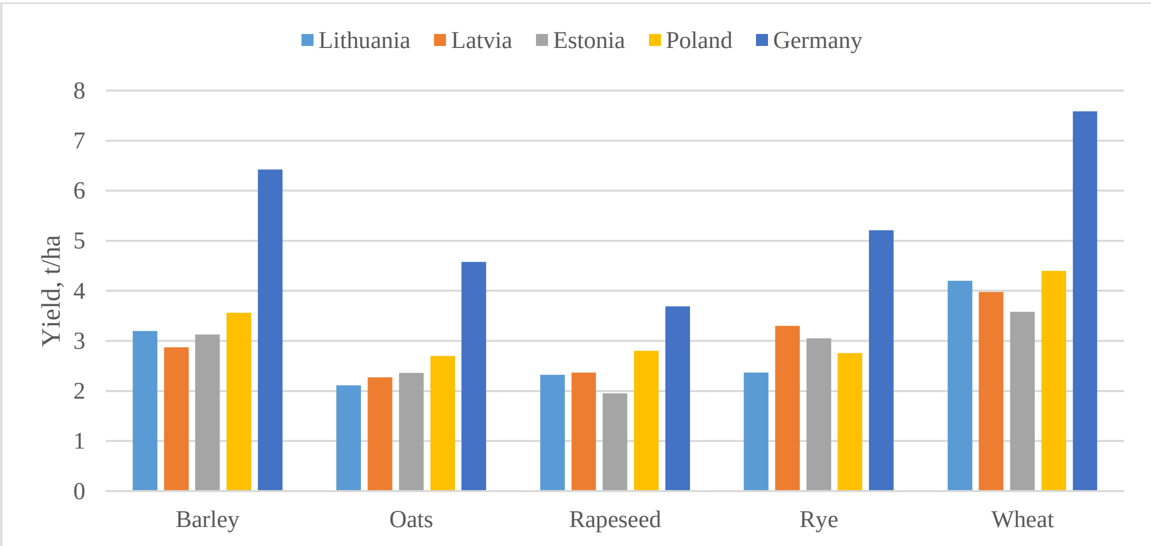

Figure 3. The average trends for selected crops, 2004-2022

Source: designed by the authors.

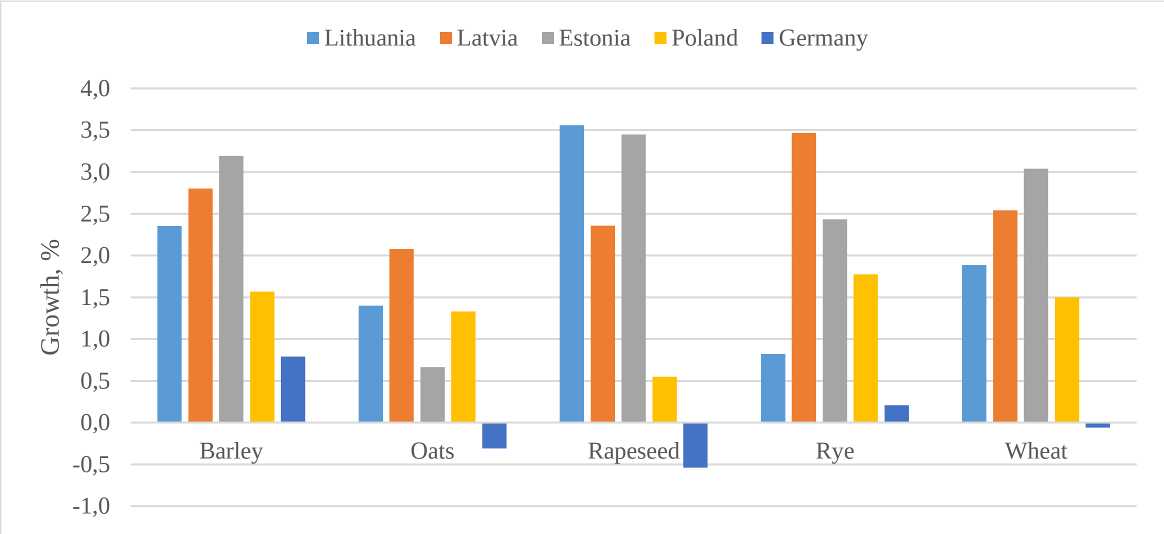

Figure 4. Growth in the yields for selected crops, 2014-2022

Source: designed by the authors.

The coefficient of variation can be used to check the differences in yields across the countries. Table 1 presents the coefficients of variation for each year and crop. The average coefficients of variation range in between 0.23 for wheat and 0.4 for barley. Thus, the inter-country yield variability is relatively similar for each crop. The trend coefficients for the coefficients of variation are negative and suggest that the yield gaps declined over 2004-2022.

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

Table 1

Dynamics in the coefficients of (inter-country) variation of yields, 2004-2022

Year	Barley	Oats	Rapeseed	Rye	Wheat
2004	0.51	0.48	0.44	0.53	0.51
2005	0.44	0.40	0.34	0.42	0.40
2006	0.58	0.62	0.54	0.45	0.57
2007	0.38	0.32	0.30	0.24	0.33
2008	0.46	0.38	0.35	0.31	0.41
2009	0.45	0.41	0.39	0.43	0.41
2010	0.51	0.45	0.44	0.44	0.43
2011	0.37	0.37	0.24	0.32	0.42
2012	0.35	0.41	0.26	0.31	0.28
2013	0.39	0.38	0.30	0.55	0.39
2014	0.36	0.38	0.38	0.40	0.38
2015	0.32	0.27	0.14	0.31	0.26
2016	0.43	0.36	0.28	0.38	0.38
2017	0.32	0.28	0.13	0.27	0.26
2018	0.41	0.38	0.25	0.30	0.36
2019	0.34	0.28	0.10	0.29	0.25
2020	0.23	0.24	0.10	0.24	0.20
2021	0.38	0.40	0.10	0.28	0.25
2022	0.30	0.30	0.24	0.28	0.23
Trend	-0.01	-0.01	-0.02	-0.01	-0.01
Average	0.40	0.37	0.28	0.36	0.35

Source: designed by the authors.

The CVs for yield can be considered as major indicators related to the yield risk. For the selected countries and crops, the CVs are calculated by looking at the time series for 2004-2022. The resulting estimates are given in Table 2. Note that two types of the CVs are reported: the conventional ones based on the average distance to the means, and the downside ones based on the negative deviations only.

For barley, the highest CVs are observed for Latvia and Estonia (0.2 and 0.25 respectively). However, the CVs for these countries are also related to the growth in the yields. The downside CVs (DCVs) are much lower and put Latvia close to Germany that showed rather stable yield series. For Lativa, the CV of 0.2 goes down to 0.07 in case the DCV is considered. As for Germany, the value of 0.09 goes down to 0.05. The DCV for barley ranges in between 0.05 for Germany and 0.11 for Estonia. The differences between the CVs and DCVs for barley are quite large given the increasing yields (Fig. 4). Thus, the use of the conventional CVs would indicate somewhat distorted picture in the sense of production risk.

As regards the variability of oat yield, the three Baltic States show the highest CVs (from 0.14 for Estonia up to 0.18 for Lithuania). The CVs for Poland and Germany stand at 0.13 and 0.08 respectively. The DCVs are twice lower (compared to CVs) for Latvia, Poland, and Germany, yet less serious differences are noted for Lithuania and Estonia. The lowest DCV is noted for Germany (0.04), whereas the highest value is observed for Lithuania (0.11).

Turning to rapeseed, the Baltic States show the CVs of 0.22-0.27, whereas the value of 0.11 is noted for Poland and Germany. The DCVs for rapeseed are more than twice lower compared to the CVs for Lithuania and Estonia. The lowest DCVs are noted for Germany (0.08) and Poland (0.06).

Table 2

The (downside) coefficients of variation for selected crops and countries, 2004-2022

Indicator	Lithuania	Latvia	Estonia	Poland	Germany
Barley					
CV	0.18	0.20	0.25	0.13	0.09
DCV	0.08	0.07	0.11	0.06	0.05
Oat					
CV	0.18	0.16	0.14	0.13	0.08
DCV	0.11	0.08	0.09	0.06	0.04
Rapeseed					
CV	0.25	0.22	0.27	0.11	0.11
DCV	0.11	0.12	0.12	0.06	0.08
Rye					
CV	0.15	0.23	0.23	0.14	0.12
DCV	0.09	0.08	0.11	0.05	0.08
Wheat					
CV	0.17	0.19	0.24	0.11	0.06
DCV	0.09	0.07	0.10	0.04	0.04

Source: designed by the authors.

The rye also shows rather high differences between the CVs and DCVs. The highest values of the CVs are noted for Latvia and Estonia (0.23), whereas Lithuania, Poland, and Germany post the values of 0.12-0.15. The maximum DCV of 0.11 is observed for Estonia. The lowest DCV of 0.05 is exhibited by Poland.

The highest CV for wheat is observed in Estonia (0.24). The second highest value of 0.19 is noted for Latvia, whereas Lithuania follows with 0.17. Note that the lowest value of the DCV is posted for Poland and Germany (0.04). Estonia and Lithuania show the highest values of the DCV (0.1 and 0.09 respectively).

In the case of wheat, the differences between the CVs and DCVs are also important as the increasing yields were noted for this crop (Fig. 4).

The analysis of the CVs and DCVs in Table 2 implies that the country and crop-wise differences in yield variation are evident. The use of the DCVs is also important given the upward yield trends that are especially relevant for the Baltic States. The measures of risk based on the downside deviation from the moving average are further discussed to show both the likelihood of incidence and magnitude of the hazard.

The hazard and probabilities of loss are calculated for the three levels of coverage viz., 100%, 90%, and 80%. Note that the existing EU regulation and the practice of insurance usually refers to the latter coverage level. The hazard is calculated as the downfall beyond the coverage level and the associated probability is computed as the number of years with specific event compared to the total number of time periods covered. Note that the hazard is measured as the relative deviation from the expected yield. Its value is negated for sake of easier presentation (thus, a certain positive number indicates a downside deviation). The resulting risk levels are presented for each crop. It turned out that some countries did not experience deviations from the yield trend exceeding 20% of the expected value. In such cases, it was impossible to obtain the risk levels. The risk levels can be considered as a basis for setting a fair insurance premium.

The risk estimates for rye are presented in Fig. 5. At the full coverage, the highest risk is observed for Estonia (6.65%). Germany, Latvia and Lithuania are clustered with risk levels of 4.09-4.99%. Finally, Poland shows the lowest risk of 2.4%. In case a 90% coverage is considered, the ranking of countries remains similar and the risk estimates for Estonia and Poland drop to 2.63% and 0.65% respectively. The risk associated with an 80% coverage is even lower: it stands at less than 1% for Estonia, Latvia, and Lithuania, whereas (almost) zero values are obtained for Poland and Germany.

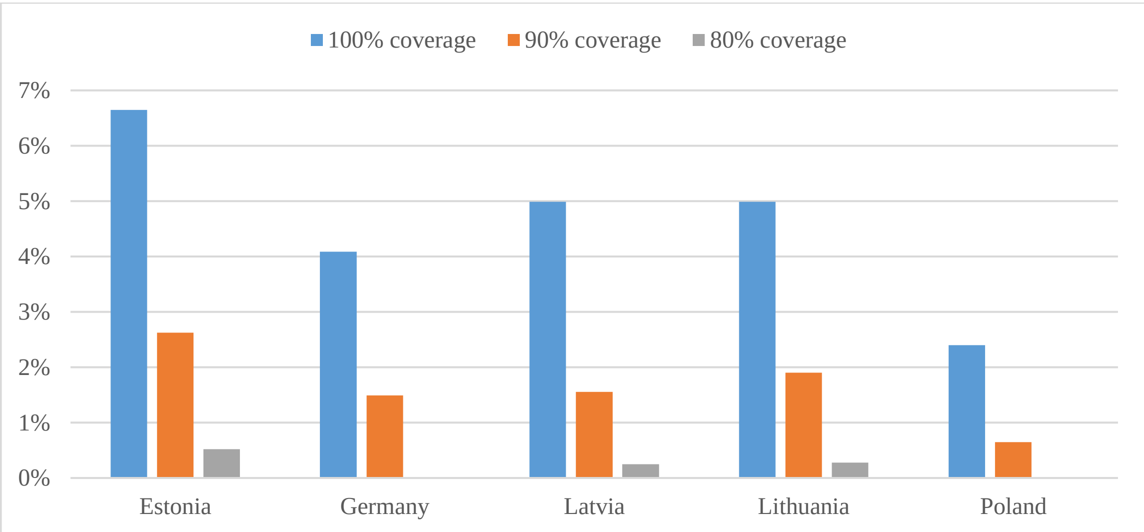

Figure 5. Yield risk for rye in the selected countries
Source: designed by the authors.

The estimates of yield risk for wheat are presented in Fig. 6. Estonia and Lithuania show the highest values of risk in the case of the full coverage (4.99% and 4.39% respectively). The lowest risk is observed for Poland (1.84%). Germany shows virtually no risk in case 90% or 80% coverage is assumed. Poland shows the risk of 0.38% for a 90% coverage and zero for a 80% coverage. For a 90% coverage, the maximum risk is that for Lithuania and Estonia of 2% and 1.89% respectively. As for the coverage of 80%, the highest risk is noted for Lithuania (0.68%).

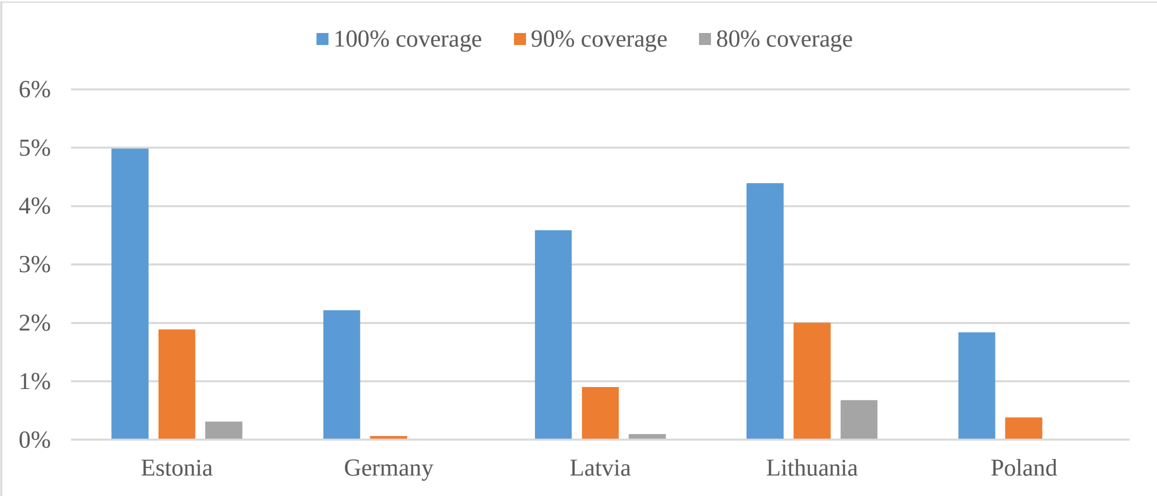

Figure 6. Yield risk for wheat in the selected countries

Source: designed by the authors.

The highest yield risk for oats is for Lithuania at all coverage levels (2.69% and 1.19% for 90% and 80% levels respectively). At a 90% coverage level, Estonia, Latvia, and Poland show risk in the range of 0.8-1.74%. As for an 80% coverage, only Lithuania shows substantial risk, whereas other countries show risk that is close to zero. Figure 7 presents the results for oats.

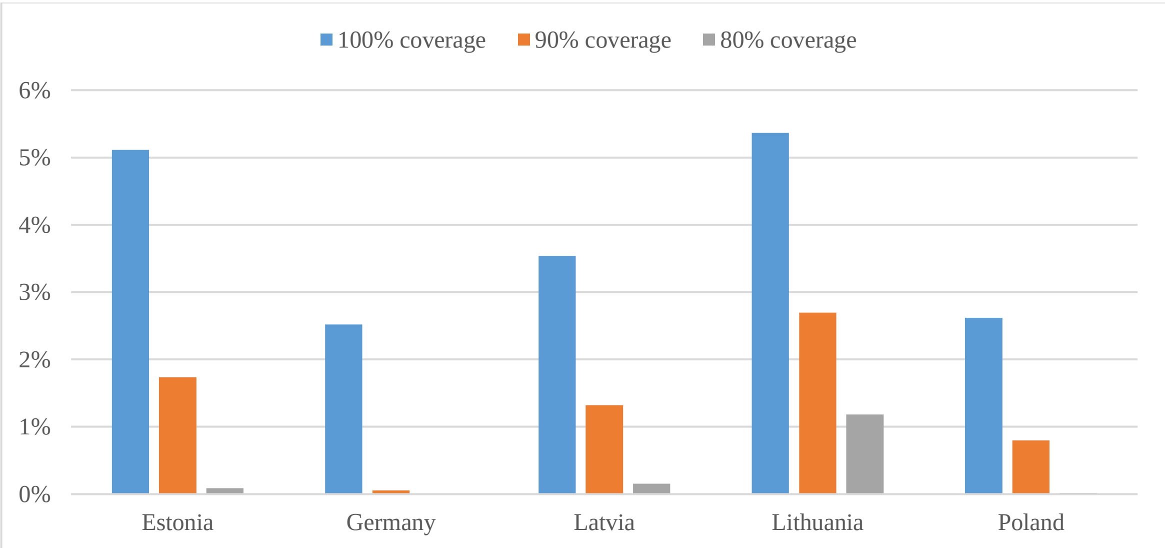

Figure 7. Yield risk for oats in the selected countries

Source: designed by the authors.

The risk measures for rapeseed are given in Fig. 8. For full coverage, Estonia shows the risk of 5.84% and Latvia that of 5.23%. The remaining countries exhibit risk of 2.52-3.54%. For a 90% coverage, the risk of 2.19-2.49% is observed for Estonia, Latvia, and Lithuania, whereas lower values are noted for Germany and Poland (1.03% and 0.36% respectively). As regards an 80% coverage, Germany and Poland show risk values that are (close to) zero, whereas risk values of 0.64-0.82% are observed for the Baltic States.

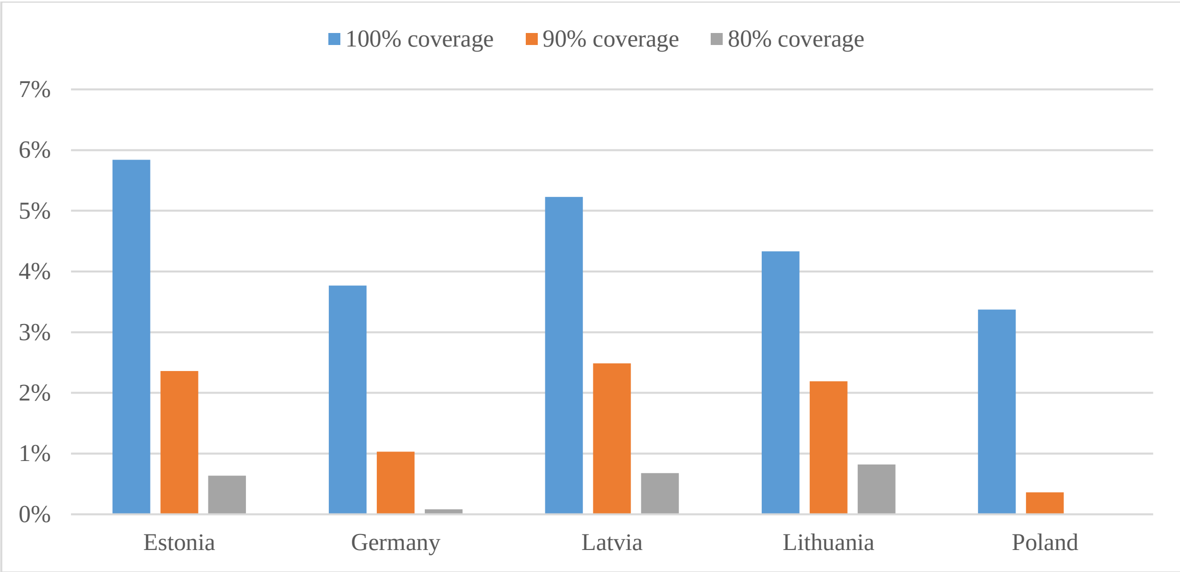

Figure 8. Yield risk for rapeseed in the selected countries

Source: designed by the authors.

The highest yield risk for barley is observed in Estonia (3.85%) and Lithuania (3.62%) assuming a full coverage (Fig. 9). These two countries also show relatively high risk levels under a 90% coverage (1.64% and 1.52% respectively) and remain the only cases with non-zero risk under an 80% coverage (0.5% and 0.22% respectively). For Germany, Poland, and Latvia the yield risk stands at 0.19-0.64% under a 90% coverage and becomes zero under an 80% coverage level.

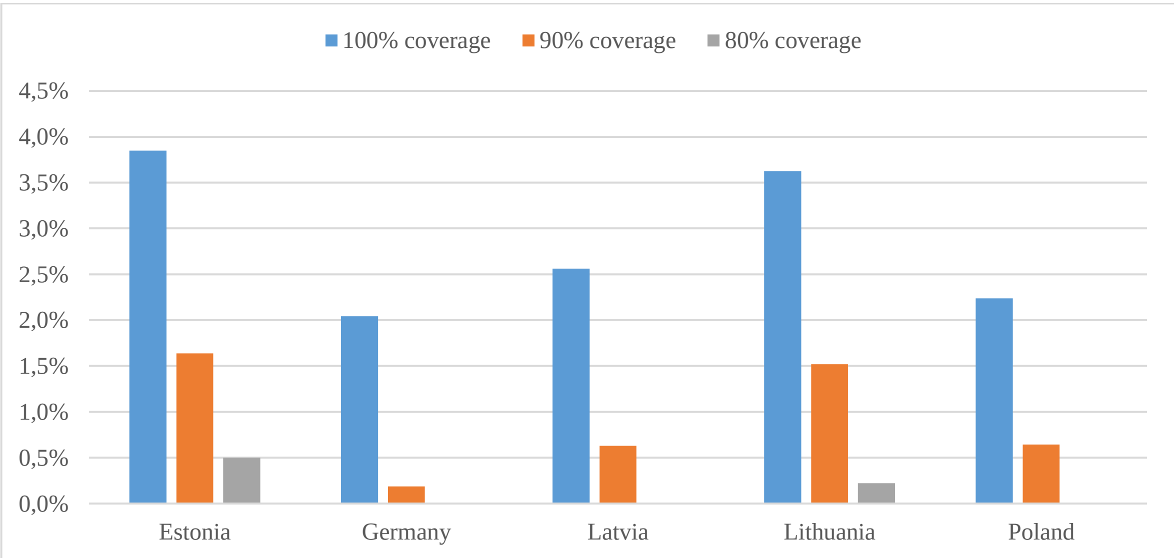

Figure 9. Yield risk for barley in the selected countries

Source: designed by the authors.

The analysis of yield risk in the selected Central and Eastern European countries suggests that the new EU member states show generally higher risk levels. The results vary across the crops. The yield gaps and yield risk gaps persist indicating the need for spreading improved farming practices across the countries in order to mitigate the undesirable effects of the environment.

5. CONCLUSION

This paper looked into the yield variability and risk in the selected Central and Eastern European countries (Estonia, Latvia, Lithuania, Poland, and Germany). The moving average was used to estimate the trends in yields and, subsequently, the hazard and risk were calculated at different levels of coverage.

The analysis suggests that the Baltic States show the highest yield risk levels for all the crops considered (barley, oats, rapeseed, rye, and wheat) compared to Germany and Poland. The area sown under these crops increased in the Baltic States during 2014-2022. Therefore, the is an increasing need to manage the production risk for these crops.

The differences across countries are more obvious than those across crops. Therefore, the country-specific solutions may be relevant in addressing the challenges related to the crop production risk in the Central and Eastern European countries. The major measures that could be taken is the adjustment of the agricultural practices to reduce the risk and establishment of the risk management measures to cope with the risk. The key role belongs to the Common Agricultural Policy measures that may be used to modernize the agricultural sector, support creation of mutual funds, and compensate crop insurance premia.

In this paper, we used a rather simple approach to estimating the risk of hazard. In the future research, one could employ different types of probability distributions to obtain more specific probabilities of observing a yield loss of a certain degree. Also, the copula approach may be used to model the dependencies between price and yield to capture the revenue risk.

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