Agris on-line Papers in Economics and Informatics

Volume III Number 4, 2011

Coherent Quantitative Analysis of Risks in Agribusiness: Case of Ukraine

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Abstract

Modern methods of quantitative risk analysis, specifically value-at-risk and expected shortfall approach, provide comprehensive and coherent risk evaluation throughout entire distribution of outcomes and can take agricultural business from the realm of uncertainty to specific, quantified risks. Monte Carlo simulation with autocorrelation of standard deviation shows the best results in risk modeling and is used for this research. The analysis showed that production risk is systemic within climatic regions of Ukraine with coefficients of correlation ranging from 0.25 to 0.85. Yield correlation among crops in several oblasts is low to negative, creating opportunities for diversification. However, positive price-yield correlation is dominant for agricultural products in Ukraine due to high dependency on global prices and a large share of export. It is hypothesized that price-yield correlation is directly proportional to the share of country's international trade in that agricultural product.

Key words

Production risk, price risk, value-at-risk in agriculture, expected shortfall.

Introduction

Risks in agriculture mainly appear as production and price risks. In spite of simple nature, these risks are substantial and can easily make an enterprise unprofitable, especially in developing economies. Agricultural risks are often difficult to quantify due to limitedness of accurate and comprehensive historical data. A combination of modern methods of quantitative risk analysis provides sufficient amount of information on risks for managers and investors managers to make adequate decisions. Ukrainian agricultural sector possesses typical risk features of a developing economy: dependability upon external price fluctuations, lack of technological innovations, high level of internal political and economical uncertainty, and ongoing land reform. Such extreme conditions are well suited for testing innovative approaches in risk assessment.

Material and methods

In the recent OECD[1] research (Antón, 2009), it has been mentioned that downside measures of risk, based on distribution of outcomes, show to be the most effective and accurate for stochastic-like risk factors such as temperature, rainfall, and price fluctuations, which make up production and price risks in agriculture. Arguably, the best approach to measuring downside risk is a modern method of value-at-risk (VaR) which is being actively adapted to agriculture from financial industry. Cotter et al. (2011) apply VaR along with expected shortfall for evaluation of price risk for agricultural products, which are sold on Chicago Board of Trade. Cabrera et al. (2009) measure crop yield risk with conditional value-at-risk to account for cyclical climate dynamics caused by El Nino. Chuan et al. (2010) use VaR method to analyze price risks of fruit markets with different types of distributions. Popularity of VaR approach is explained by its ability to combine all risk factors into one measure, based on portfolio theory. The most comprehensive and profound description of VaR methodology is given by Jorion (2003), including grounds for normal distribution preference. In case of Ukraine, where statistical data is insufficient for any historical modeling, Monte Carlo approach to finding VaR is deemed the most appropriate. Monte Carlo method is used to check accuracy of other VaR measures by Herwatz (2009) and Wong (2010), which makes it inherently superior. In addition, Monte Carlo simulation accounts for heavy tails,

[1] Organisation for Economic Co-operation and Development

which are common in price fluctuations and recent temperature trends.

While price volatility is cyclical and price shocks tend to be repetitive through decades (at least in percentage terms), factors that affect production rapidly change. On one hand, there is global warming that increases temperature swings and alters rainfall cycles, on the other hand, advances in biotechnology bring more resilient to drought sorts of crops. Therefore, when analyzing crop yields, some sort of autocorrelation should be used to account for the changing balance between climate change and technology, as shifts in this balance make volatility a dynamic variable. For this, simple GARCH[2] 1,1 model (Bollerslev, 1986) should suffice, considering that it is implemented into Monte Carlo simulation and calculations may seem tedious as is. GARCH volatility is widely implemented into different approaches of VaR calculations, and as shown by Iorgulescu et al. (2008), it indeed appears to improve accuracy.

Despite being the most wraparound, it is widely accepted that VaR alone does not provide a complete picture about risk as it covers only a part of a distribution, specifically a confidence interval. A tail, which is often heavy and significant, remains outside of VaR's reach. Although a probability of an event happening outside of a reasonable confidence interval is unlikely, in agriculture it represents catastrophic events and risks that they carry. Especially in the light of recent climatic events, such as droughts that regularly set 30-50 year records in various regions (e.g. Russia in 2010, France and UK in 2011), catastrophic risks must certainly be accounted for and given an adequate weight during risk evaluation. Also, Ukrainian government does not provide support to agricultural producers in case of catastrophic events, which makes catastrophic risks even more relevant. To solve this problem, a conditional measure of risk, also known as conditional value-at-risk (CVaR) or expected shortfall (Yamai et al., 2005), is used. Daníelsson et al. (2006) shown that most downside risk measures, including expected shortfall, provide even results as they all interpret heavy tails in a similar manner. It is logical to use expected shortfall with VaR as they complement each other according to Szegö (2002). In case of this research, expected shortfall is defined by arithmetic mean of the tail of the distribution. Combination of VaR and expected shortfall measures make up coherent evaluation of risk.

In order to adequately evaluate agricultural risks, a confidence level of 90% is chosen, where VaR shows the worst probable outcome that shouldn't be exceeded more than once every 10 years (for yearly data sets), with everything that occurs rarer and with greater negative impact considered a catastrophic risk. 10 year interval is justified by an approximate pay-off period of an average agricultural enterprise in Ukraine.

Results and discussion

Production risk

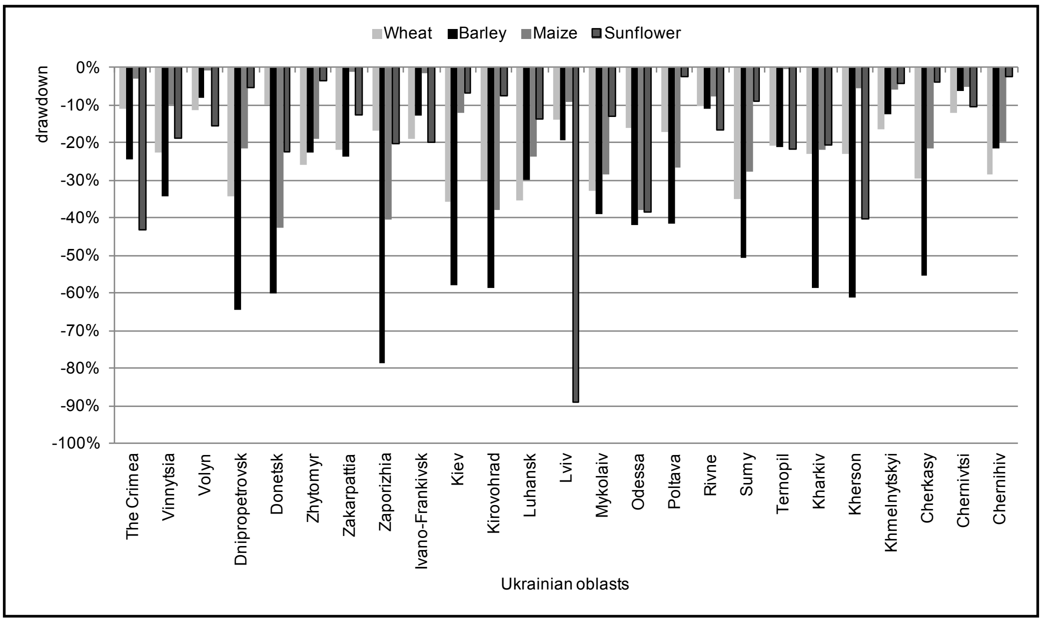
Among the most popular and profitable crops that are grown in Ukraine are consistently wheat, barley, maize and sunflower. Yet, due to variety of climatic regions, deviations of yields from these crops differ considerably between oblasts. Using distribution methods, described in previous section, possible declines in yields, which should not happen more often than once every ten seasons, are determined (fig. 1).

It is evident that that some traditional crops are too risky for certain regions, such as sunflower in Lviv or barley in Zaporizhia. Such crops may be avoided in crop rotations and replaced by less profitable, but with lesser risk.

Table 1 shows quantitative measures of decline in yield, obtained by calculating VaR at 90% confidence interval (also showed on fig. 1), and losses which are likely to occur in case of a catastrophic event (when confidence level is breached). Official statistical data was used for all calculations, provided by State Statistics Committee of Ukraine (Lukjanenko, 2010, State Statistics…). It is important to state that the data sample was rather small: only 6 years of generalized data for each oblast. For businesses in many small countries, including Ukraine, only such limited data is likely to be available. It is noticeable, that a detailed picture of risk could be projected with only 6 samples (years) of data per oblast.

Catastrophic risks in many oblasts for some crops are quite low, especially for maize and sunflower. For instance, maize production catastrophic risk in western oblasts of Volin, Ternopil, Zakarpattia, Ivano-Frankivsk is within 7%, which makes costly risk reduction measures, including insurance, unnecessary. Sunflower yields in central Ukraine are less volatile and stay within 20% even in case of the most extreme circumstances. Data also shows that some crops are intrinsically detrimental to cultivate in some areas of the country. Those crops that possess catastrophic risks over 100% are likely to be wiped out by droughts or floods due to the climatic features of that region. Considering weak government support of agricultural insurance in

[2] Generalized Autoregressive Conditional Heteroskedasticity



Source: Author´s research.

Figure 1: Possible drawdown from production risk for crops in each oblast in Ukraine.

Ukraine, it is likely that insurance products for high risk crops will not be available for certain areas.

Coherent risk analysis, which interprets the full probability density function (PDF), gives managers an idea of how to form financial and business strategy, aids in planning, and helps to adequately choose risk minimization policies. Its main advantage is a currency form. In this paper, Ukrainian currency is substituted by percentages to make results more apprehensible for international readers. In business management, however, currency-denominated risk figures are extremely convenient.

One thing to notice is that each crop is viewed as a separate asset in this paper, while all risks, which influence production, are approached as a portfolio. While analyzing combinations of crops, one can choose two approaches: combine selected crops into a portfolio and apply coherent PDF analysis to each combination, or calculate correlation between crops separately and just choose preferred crops based on the minimum variance approach. During the early stage of this research, it became apparent, that the latter is much easier and just as efficient.

Two types of correlations typically interest risk managers in agricultural production. One is a measure of systemic risk, which measures yields of a single crop across various areas. The other shows how yields of different crops correlate in the same area. Production risks seem to be systemic within three main climatic regions of Ukraine: Steppe, Forest-steppe, and Woodlands. Figure 2 depicts correlation of crop yields through oblasts for each region. Such high correlation signifies that producers tend to experience losses simultaneously, which has several major effects. With high level of systemic production risk, price volatility on domestic market tends to increase, along with negative price-yield correlation. Also, systemic risks are harder to pool and that limits choices of available instruments for risk management for agribusinesses. It appears that relationship between correlations and risk in agricultural production is more complex than linear or geometric. This is an argument for the use of individual approach in crop production risk analysis. Portfolio approach would imply that diversification is always possible at a reasonable cost and any amount can be diversified into. Such implications seem unrealistic for most agricultural businesses. Hence, correlations ought to be taken into account, but kept outside of coherent risk analysis model.

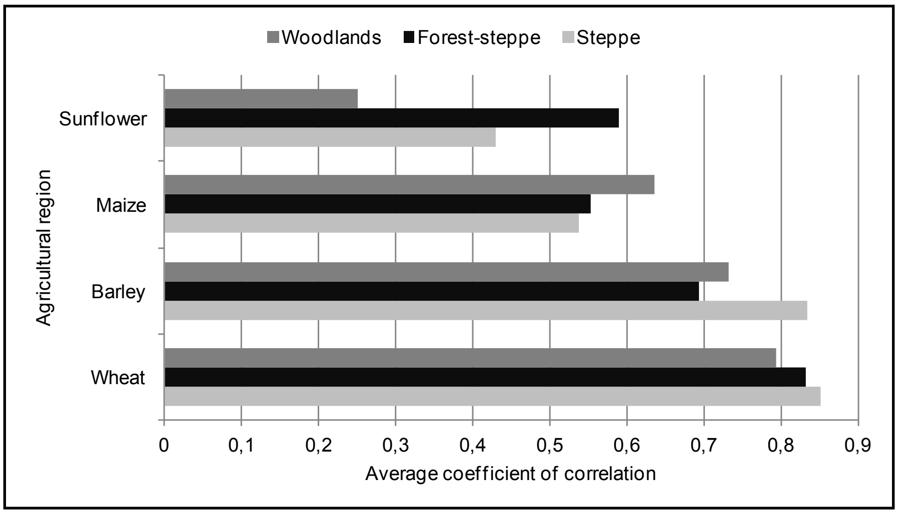
Among factors that cause high systemic risk are mainly droughts that consistently effect large areas, often entire regions. Wheat and barley yields uphold the highest level of intraregional correlation in Ukraine, as the most affected by droughts. However, wheat's average yield volatility is relatively lower, as shown in table 1, and the risk is less tangible.

For some areas, diversification remains the only viable method of risk management, especially where risks are too systemic to be marketable. Negative correlations between crop yields in several oblasts are observed. Table 2 shows a correlation matrix of the lowest correlations among yields within oblasts.

	Possible drawdown in yield, %				Catastrophic risk, %			
Area / Crop	Wheat	Barley	Maize	Sunflower	Wheat	Barley	Maize	Sunflower
Ukraine	-20.8	-37.1	-9.3	-5.5	-33.3	-64.3	-15.4	-10.3
Oblasts								
The Crimea	-10.8	-24.2	-3.1	-43.3	-17.3	-40.0	-25.2	-70.2
Vinnytsia	-22.7	-34.2	-10.0	-18.9	-32.0	-51.9	-24.6	-22.5
Volyn	-11.3	-8.2	-0.7	-15.5	-16.7	-19.8	-6.6	-27.8
Dnipropetrovsk	-34.2	-64.6	-21.5	-5.4	-53.4	-83.2	-29.0	-7.8
Donetsk	-9.8	-60.1	-42.8	-22.4	-26.7	-83.0	-75.4	-30.5
Zhytomyr	-26.0	-22.5	-18.9	-3.6	-37.8	-34.5	-33.0	-11.0
Zakarpattia	-22.0	-23.8	-1.1	-12.7	-29.5	-33.4	-3.3	-18.4
Zaporizhia	-16.9	-78.7	-40.6	-20.4	-314	-119.5	-62.0	-30.9
Ivano-Frankivsk	-18.8	-12.6	-1.6	-20.0	-25.1	-22.6	-6.8	-30.6
Kiev	-35.9	-57.9	-12.0	-6.8	-50.1	-79.6	-22.2	-13.0
Kirovohrad	-30.0	-58.5	-37.9	-7.5	-44.4	-104.4	-53.9	-11.9
Luhansk	-35.4	-30.0	-23.6	-13.8	-77.3	-58.5	-38.5	-21.0
Lviv	-14.0	-19.2	-9.3	-89.2	-21.2	-30.9	-14.9	-134.0
Mykolaiv	-32.9	-39.1	-28.5	-13.0	-53.2	-73.7	-56.7	-17.6
Odessa	-16.2	-41.9	-37.8	-38.6	-32.7	-65.8	-76.9	-62.6
Poltava	-17.2	-41.5	-26.7	-2.4	-43.5	-60.3	-32.7	-9.0
Rivne	-10.1	-10.8	-7.5	-16.7	-12.1	-15.6	-12.1	-62.1
Sumy	-34.9	-50.5	-27.5	-9.1	-46.6	-63.4	-45.1	-23.3
Ternopil	-20.8	-21.0	-0.3	-21.8	-32.4	-28.5	-2.4	-35.7
Kharkiv	-23.0	-58.5	-21.7	-20.5	-52.0	-73.8	-29.8	-30.2
Kherson	-23.0	-61.3	-5.5	-40.1	-34.1	-91.5	-13.4	-55.2
Khmelnytskyi	-16.5	-12.3	-6.0	-4.3	-26.7	-18.3	-10.2	-16.4
Cherkasy	-29.4	-55.4	-21.6	-3.8	-37.8	-81.6	-32.1	-12.1
Chernivtsi	-12.1	-6.3	-5.3	-10.5	-25.8	-12.4	-9.9	-12.4
Chernihiv	-28.5	-21.5	-19.5	-2.5	-46.9	-33.7	-29.0	-10.1

Source: Author´s own research.

Table 1: Production risk measurements across Ukrainian oblasts for major crops.



Source: Author´s research.

Figure 2: Correlation of yield across oblasts in different climatic regions.

Oblast	Crop	Wheat	Barley	Maize
The Crimea	Sunflower	0.04	0.09	-
Volyn	Sunflower	-0.29	-0.07	-
Zhytomyr	Maize	-	-0.07	-
Kharkiv	Sunflower	0.13	0.08	0.11

Source: Author´s own research.

Table 2: Notable low correlations of yields in Ukrainian oblasts.

Price risk

Price volatility in Ukraine is similar to that on global markets, which the country is well integrated into. Coefficient of variation between wheat prices in Ukraine and CME Group for the past two years (2009, 2010) is around 16%, with correlation of approximately 55%. However, impact of volatility of prices on Ukrainian agricultural enterprises is greater because there are fewer instruments for price risk management. Price risk in Ukraine is less marketable than in developed economies due to unavailability of standardized futures contracts. Forward agreements are hardly enforced and only work for trusting partners. Forward contracts are used more as a crediting tool with flexible or unspecified price and are hardly suitable for price risk management.

Table 3 demonstrates price risk measures, obtained by previously described methods, for most agricultural products. Types of agricultural products are subject to a certain level of aggregation due to peculiarity of available statistical data. Nine years of yearly data were chosen as a sample, starting at 2003 up to 2011. September and February are picked as significant data points because September marks immediate sale price after harvest, as opposing to February sale price after 6 months of storage. Crops, which are easy to store, such as wheat and potatoes, are exposed to similar price risk throughout the year. Vegetables and oil crops are more problematic to store for many businesses, and their supply half a year after the harvest is uncertain. The lesser is supply, the higher the price volatility and risk overall.

Note that modeled risk measures are hypothetical and, considering recently increased volatility in commodity markets, tails of distributions drag over -100%, which simply means that price declines are likely to be very rapid and a full range drop may occur within just a few months. Even though 100% declines in price are impossible in the real world, it gives an accurate idea of a great extent of possible losses. Overall volatility has considerably increased for commodities such as wheat, rice, beef, sugar, according to Onour et al. (2011). Many examples of 70-75% drops in commodity prices have been seen during the financial crisis of 2008-2009 (CME Group…).

Under existing mathematical methods, there appears to be no feasible way to avoid modeling results below -100% without upsetting conceptual framework by vague assumptions. Widely used for limiting lognormal distribution will not work, because it generates long right tail, which may create an illusion of a positive sum game and provoke risk taking behavior (e.g. gains are greater than losses). Or vice versa, depending on how the neutral outcome is defined in the distribution. Therefore, it seems optimal to equate values around -100% to historical maximum loss.

As described before in this section, correlations are analyzed separately from coherent risk analysis methodology to facilitate risk minimization measures later on. As opposed to production risk, where correlation of yields matter most, price risk management requires measurement of price/yields correlation to determine economic effect, which decline in price should have upon a business unit.

Month/ Product	Grains and leguminous crops	Sunflower seed	Potato	Vegetables	Livestock and poultry	Milk and dairy products	Eggs
	Possible price decline, %						
Sep.	-22.73	-27.75	-35.06	-23.97	-6.13	-22.75	-11.44
Feb.*	-28.30	-126.79	-38.69	-82.79	-2.92	-22.25	-21.64
	Expected maximum decline in price, %						
Sep.	-41.64	-52.94	-48.54	-35.31	-21.86	-45.15	-28.00
Feb.*	-63.68	-157.82	-66.48	-140.06	-9.70	-38.78	-39.54

*February of the next year

Source: Author´s own research.

Table 3: Price risk measurements for crop and animal production.

	Grains and leguminous crops	Sunflower seed	Potato	Vegetables	Livestock and poultry	Milk and dairy products	Eggs
Sep. price	0.36	0.69	0.40	0.61	0.72	-0.93	0.87
Feb. price*	-0.04	0.34	0.41	0.51	0.80	-0.93	0.76

*February of the next year
Source: Author´s research.

Table 4: Correlation of price and yield.

It is typical to have negative correlation between price and yield in agriculture, which reduces revenue variability considerably. Such negative correlation is referred to by Harwood et al. (1999) as a natural hedge due to its property to passively reduce risk. However, because prices for most agricultural products are mainly formed globally, low domestic yields do not guarantee higher sale price. In Ukraine, impact of lower yield on price is even less, as a large portion of products are exported at international prices. Table 4 shows evidence of positive correlation between price and yield for all agricultural products except for milk and dairy, which are sold domestically with a small portion exported to Russian Federation. Correlation of yield with February price (after approximately six months of storage) tends to be mostly lower, as a large portion of crops have already been exported by that time and, if harvest was poor, shortages start to occur.

Fundamentals behind risks

Coherent risk analysis is purely technical and does not include fundamental factors in a model itself. It is useful to recur to fundamental factors to gain intuition of conditions, in which the model operates. Description of fundamentals should also be helpful for readers, who wonder how coherent risk analysis would work in other economic environments. Although, described methodology does not have any known limitations.

Most of the volatility in yields is caused by droughts and inability to effectively gather harvest due to weather factors and poor technical equipment. In western part of Ukraine floods are common, while droughts prevail in south-east. Technical equipment is available on the market, but capital is often too costly for many producers, as farm land cannot be used as collateral according to Ukrainian law. Borrowed capital cost often rises up to 30% and, as a result, many producers choose to sacrifice a portion of yield by avoiding purchase of new equipment.

Price risks include currency fluctuations and risks that come from currency exchange. Financial products, such as currency futures, that would allow businesses to hedge currency pairs are not available, and currency risk is left entirely to be absorbed by agricultural businesses. Currency risk technically becomes a component of a price risk. Ukrainian currency floats freely, but National Bank of Ukraine sets a very narrow corridor for fluctuation of Ukrainian currency to the United States Dollar. Such policy almost eliminates currency risk in a short term, but eventually when a financial crisis hits (such as in 2008) and National Bank's reserves become insufficient to maintain the policy, national currency may depreciate instantly by over 50%.

A lot of uncertainty comes from subsidies that businesses count on. Subsidy payments are often delayed, postponed, or declined entirely for various reasons. Share of subsidies in income is often small and the chance of receiving it is always unknown. In such conditions, some enterprises choose to discount subsidy income entirely, yet others are forced to account uncollected subsidies as losses. Regardless, uncertainty of cash flows from sales caused by subsidies counts towards price risk. Exporters also face uncertainty during value added tax return, for which the government continuously has an outstanding debt.

Conclusion

Distribution-based methods of risk assessment, specifically, value-at-risk and expected shortfall are best suited for measuring price and production risks in agricultural production. Monte Carlo simulation enables modeling under conditions of limited historical data, while autocorrelation accounts for any volatility trends even in small data samples. It is observed that production risk varies greatly for different crops in Ukrainian oblasts. Also, the risk is of systemic nature, and is highly correlated inside climatic zones of the country. Some low to negative correlations for a few crops in four out of 25 oblasts are observed. Price risk appears to follow global price volatility, except for popular in Ukraine sunflower seeds, price of which appears to fluctuate considerably. There is evidence found, that price-yield correlation is constantly positive throughout the year, except for milk products and grains after the end of the harvest season, which is explainable by export orientation of the country's agricultural producers.

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