

FARM INCOME RISK ANALYSIS AT THE SECTOR LEVEL

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Abstract

Macroeconomic developments on international agricultural commodities' markets have in recent years considerably amplified interest of income risk management in agriculture. In EU countries this is also new prospective of further agricultural policy development. Therefore, there is a need for empirical analysis and tools aimed at providing in depth insight into the topic. For preliminary decisions and for efficient and effective agricultural policy planning, magnitude and characteristics of income risk that agricultural holdings face, have to be analysed from different viewpoints. Indirect income risk analyses demands high quality microeconomic data at farm level, which are in most cases not available. This paper presents possible theoretical approach how different sources of data at farm level, national statistics and analytical models could be merged and utilised in simulation process to analyse income losses at the sector level. It is grounded on production structure resumed out of annual subsidy applications as key information per each agricultural holding. Presented approach's utilises potential of random number generator and random distributions of Monte Carlo to roughly reconstruct different sources of risks in different states of nature that may occur with diverse probabilities at the particular farm. In such a manner income situation at the farm level is analysed. The developed approach is tested on dairy farms in Slovenia. Obtained results suggest that this could be useful approach for rough estimation of income risk and points on some limitations and drawbacks that could be further improved.

Keywords: risk, income losses, simulation, agriculture, MCS

1. Introduction

In recent years high volatility on agricultural markets parallel with global financial crisis has amplified interest in risk management in agriculture; particularly income risk. Risk management has become also a major policy issue of on-going agriculture policy reforms in OECD and also non-OECD countries (OECD, 2011), since whole-farm income is the best measure of the welfare of agricultural holdings. Stabilizing whole farm income therefore appeals to policy makers (Meuwissen et al. 2011). In many countries this intention has hit on the problem of insufficient data sets for this purpose, especially for analyses of holistic risk management approach. Namely, risk management at the level of agricultural holding is very demanding from information viewpoint (Anton et al., 2011). It requires utilisation of all available information about different risk sources at the level of each particular agricultural holding. The availability of historical farm level data is a major constraint in the analysis of the risk exposure of individual farms (OECD, 2011). Beside farm level microeconomic data, it is also important to have reliable information regarding market developments (Tangermann, 2011).

Lack of fact-based knowledge about risk at the individual agricultural level could be significant problem in changing agricultural policies where risk management is becoming an important issue. OECD (2011, 22) is stressing that this might represent additional source of uncertainty perceived by farmers. Namely, risk assessment is a necessary first step to develop a good risk management strategy (OECD, 2011). Simulation approach presented in this paper aims to support studying income risk at the sector or regional level.

Farms face different varieties of risks that directly influence their income. Agriculture output variability is tightly connected with natural hazards and consequently also with large price fluctuations, both specific for agriculture (Tangermann, 2011). Agricultural holdings can however also benefit from some correlations in managing their risk, as for example imperfect correlation between yields and negative correlation between prices and yields (OECD, 2011). But even if - on average - market mechanism reduces total variability, this does not necessarily apply to each individual agricultural holding (Tangermann, 2011). Namely, volatile prices most often reflect situation on international markets and have small correlation with domestic output variation. Similarly holds for variation in production output that most often affects a group of agricultural holdings, except if risk caused this is systemic. Either outlined facts hold also for farmers in Slovenia, regarding the influence on the market prices. Additional volatility enters through risks arising from other economic sectors. Such an example are energy-intensive inputs' prices (Tangermann, 2011).

First condition to conduct income risk analysis is series of appropriate data. The most appropriate data for this purpose is very accurate accounting system linked with other databases with enough long data series (Anton et al., 2011). In the literature one can find many examples how FADN data could be applied to analyse income risk and efficiency of income risk management. Such examples are Vrolijk and Poppe (2008), Severini and Cortignani (2011); OECD (2011); Majewski et al. (2007). However, even though FADN data are appropriate for such analysis, problem might arise if the data quality is not appropriate or if the sample of agricultural holdings is not adequate to systematically cover the whole agricultural sector. Issue might be also changing sample of agricultural holdings. Common approach in such type of analysis is extrapolation of results from the sample of agricultural holdings to the whole sector. To gain additional information by analysing income issue, this paper suggests opposite approach, designed on including different data sources for majority of agricultural holdings with few or no micro-economic data.

Paper presents theoretical simulation approach how analyses of income risk at the level of agricultural holdings could be conducted without appropriate microeconomic data per each farm, but on the basis of actual production structure and characteristics of income distributions based on national data set and expert judgement. Aim is to get rough estimation of income risk of whole agriculture and of individual sectors. Beside different methodological concept we are mainly interested in analysing characteristics of income risk. Through basic statistics such as measures of central tendency and variation considering confidence intervals, risk measures and quintile measures, better insight into the analysed problem is given. However, it has to be noted that individual risk environment faced by particular agricultural holding can significantly differ from sectoral or aggregate risk (Kobzar, 2006; OECD, 2011). Consequently, suggested approach is not appropriate for in-depth analysis of income risk at particular agricultural holding.

Monte Carlo simulation (MCS) proves as a powerful method for conducting quantitative risk analysis. Approach of random sampling is especially beneficial when there are several sources of uncertainty that interact in the calculated outcome - income in our example. Main idea is that uncertain variables, represented as random number generators (RNG), return sample value from a predefined distribution of possible values for each uncertain variable in each replication of the model. In literature one could find numerous examples how potential of RNG has been utilised for risk analyses in the field of agriculture. For example Kimura and Anton (2011) utilized Monte Carlo simulation to analyse the effectiveness and efficiency of farm income stabilisation programs in Canada using AgriStability payments. Majewski et al. (2007) have utilised MCS method in a static simulation model to estimate the level of volatility of farm incomes on six most often production type in Poland. Anton et al. (2011) utilised MCS to model a farm producing multiple crops under different uncertainties.

Based on this background, the aim of our paper is to present a theoretical bottom up approach how income risk could be analysed on different levels of sector, economic groups of agricultural holdings. Paper presents development of a preliminary attempt to assess the soundness and applicability of the proposed simulation tool. It has been tested on Slovenian dairy farms to consider its strengths and weaknesses and to identify further needs of improvement.

The paper continues with concise description of applied approach and developed simulation tool. It is followed by in-depth description of setting uncertain variables as well as basic characteristics of the data-base. The contribution concludes by obtained results and discussion.

2. Material and methods

2.1. Database

Main information of particular agricultural holding's characteristic are annual data collected by Slovenian Payment Agency regarding subsidy applications (IACS). For the purpose of this study we considered data for CAP 1st pillar payments and also for LFA payments. Benefit of this approach is that we can analyse all farms applying for subsidies regardless if they practice accounting or not. Consequently almost all agricultural holdings in the sector could be analysed with suggested approach.

From IACS database it is possible to gather information about physical production structure for each particular agricultural holding in given period. In the current tool we considered data for the 'subsidy' years 2010 and 2011.

In this way we get some information about all agricultural holdings in particular agricultural sector, however without necessary micro-economic data (like from accounting) for proper analysis of income risk. This is also the main disadvantage of applied approach. Therefore the main challenge was to estimate achieved revenues, gross margins and incomes per each agricultural holding. And even bigger issue was to imitate income risk. Further we present possible conceptual approach how to merge different data sources to mitigate this challenge.

In the first step standard outputs (SO¹) for all activities included into the model have been defined. For this purpose we considered values already calculated for another study that utilised the same source of data (Rednak, 2012). SO per activities were calculated based on the average data for the period 2005-2009, derived from internal data sources prepared by Agricultural Institute of Slovenia. Further SO at the level of agricultural holding has been calculated based on methodology proposed by European Commission (Rednak, 2012).

In the database 59,632 agricultural holdings are included, divided into 22 farm types. For the purpose of this study and to demonstrate developed approach we will focus just on dairy farms. In this group we got 5,909 agricultural holdings. Further these farms are divided into 11 economic classes that are classified regarding to achieved whole farm SO.

Main disadvantage of this approach for risk analysis is that for all analysed farms in the model the same average productivity and average market prices are considered. To decrease the influence of this mistake, additional indices to adjust SO for crucial activities have been calculated. Such an example is SO for milking cows that is corrected for deviation from average milk production in lactation and average milk production by farm (calculated as farm milk quota divided by the numbers of dairy cows in the herd). Similarly SOs have been corrected for crop activities. In this

¹ The standard output of agricultural production means the monetary value of output corresponding to the average situation (average values over a reference period).

case we have considered that total arable land that agricultural holding possesses could influence the efficiency of production. Smaller plots of arable land per farm (smaller than the average national production significant for particular sector) result also in lower SO and vice versa. In both examples five different indices were considered, ranging from -15 to +15 %.

To get total average revenues per agricultural holdings, SOs were increased for eligible subsidies from the first and second pillar of the CAP. Since most subsidies are decoupled it was not possible to directly estimate revenues per activity. This was considered also by defining costs. Namely, variable cost and fixed costs are calculated in the model as a relative share of SO per each activity. This share has been denoted on historical data set prepared by analytical Model calculations (AIS, 2013).

2.2. Developed tool and simulation model

The main challenge was to estimate income risk for all agricultural holdings in analysed sector. To assess the effect of different normal and catastrophic risks that holdings might face by farming, we developed a complex simulation toll reflecting income loss at whole-farm level.

Simulation tool has been developed in a spreadsheet platform using MS Excel and Visual Basic. To run simulations, additional professional simulation software package, Risk Solver Platform V 10.5.0.0 (RSP) from Frontline Systems has been applied. Beside advanced methods to perform simulations, it enables sensitivity analysis and parameterized simulations, creating a wide range of statistics and risk measures. Simulation is performed based on MCS that are often applied for studying different systems involving uncertainty. It relays on random sampling of values for specified uncertain variables included into simulation model, based on Latin Hypercube sampling.

Simulation tool is organised as mathematical model. It covers 40 different basic activities including livestock, crop production, forage, vegetable and fruit production. With additional static indices (e_i) calibrating baseline activities' SOs, the number of activities further increases (e.g. instead of 1 dairy production activity the model includes 5 different technologies).

So far static economic results per agricultural holding are considered. For risk analysis this is not enough, since one is interesting also in possible deviations from expected revenues, gross margins and incomes within different states of nature. This uncertainty was included through additional random variables, based on frequency distributions analysis, representing possible states of nature for SOs and variable costs. Namely, simulations require probability distributions for their uncertain inputs, from where the simulation model randomly selects sample values.

Regarding the fact that this is preliminary version of the tool and to keep it at this development stage simple, for all uncertain variables addressing farming activities, common triangular uncertain distribution is considered. It is defined by minimum (X), maximum (Z) and most likely (y) values. Set of deflated historical data (AIS, 2013) were analysed to determine how SOs and variable costs for each activity change within the time.

Simulation model simulating achieved income (I) per agricultural holding (f) in different states of nature (j), could be defined as follows:

$$I_{fj} = GM_{fj} - FC_f$$

$$GM_{fj} = \sum_{i=1}^n GM_{ij} + SUB$$

$$GM_{ij} = SO_i e_i a_{i_s j} - SO_i * P * b_{i_{ss} j}$$

$$a_{i_s} = \text{Triangular}(x_{i_s}, y_{i_s}, z_{i_s})$$

$$b_{i_{ss}} = \text{Triangular}(cx_{i_{ss}}, cy_{i_{ss}}, cz_{i_{ss}})$$

$$s = \text{Binominal}(s_1, s_2, s_3; p_{s1}, p_{s2}, p_{s3})$$

$$ss = \text{Binominal}(ss_1, ss_2; p_{ss1}, p_{ss2})$$

Where FC_f is presumed to be fixed without change in different states of nature. GM_{fj} represents the total gross margin achieved at the level of agricultural holding, which is the sum of all n activities gross margins GM_{fj} that agricultural holding operates, with different values between states of nature j . SUB includes all subsidies from the first pillar including historical payments as well as LFA payments. All subsidies are presumed to remain unchanged within simulation process. a_{i_s} is index generated from triangular distribution to adjust SO_i , of activity i , per each state of nature j in respect to selected scenario s . e_i is static coefficient to adjust average SO_i of activity to particular farm characteristics (e.g. milk production). Variable cost is calculated as percentage P of SO_i and $b_{i_{ss} j}$ is index generated from triangular distribution to adjust variable cost per each state of nature, regarding the selected scenario (ss).

Within simulation process, different scenario representing different level and type of risks (normal/catastrophic, correlated/uncorrelated, systemic etc.) at the level of SOs and variable costs are presumed. Two uncertain variables (and) are plugged into the model to randomly select scenario which is in place in particular state of nature for SO and variable costs per analysed agricultural holding. Common binominal distribution was assumed in both cases with defined probabilities of occurrence. Consequently five uncertain coefficients were defined for each parameter of activities' triangular distribution in the model: three different for SO scenarios (s) and two different for variable costs scenarios (ss).

First scenarios in both cases include 'normal risk' or most likely deviations. This means that minimum and maximum values are in the range of 'normal' ten years period. Second scenario was defined only for SO and includes greater possibilities for extremes (positive correlation between risks) from first scenario and the range of possible outcomes (min and max) is widened. The third scenario of SO and second scenario for random variable costs anticipates catastrophic or extreme events, with significantly high frequencies of very bad as well as very good outcomes. In most cases this means that outcome could be also zero or something close to zero, less likely it is that outcome would be something very good. Just vice versa holds for logic in defining uncertain indices for variable costs. Which scenario is selected in a particular state of nature depends on discrete uncertain variable, based on binominal distribution.

In proposed analysis simulation includes 10,000 states of nature, which means that outputs per each activity and agricultural holding was calculated for 10,000 randomly sampled values.

3. Results

Even though the main focus of this paper is description of developed tool, an example of possible analysis it enables is presented. For in-depth analyses of income risk different statistical functions are included. Through PSI (Polymorphic Spreadsheet Interpreter) functions of RSP, it is enabled to follow basic statistics for all simulation runs per each of analysed agricultural holding.

In this paper aggregated results for whole dairy sector and one frequency chart for a farm with SO between 15.000 and 25,000 € are presented.

Since simulation always yields whole range of possible outcomes, it is very important how results are analysed and interpreted. In developed tool in-depth analysis of this viewpoint is conducted. In the first step measures of central tendency as mean, median and mode for expected income are calculated. Additional information for each analysed farm has been calculated also with quintile measures such as percentiles, cumulative targets, value at risk (VaR) and conditional value at risk (CVaR). In Table 1 few of these results at the level of different SO groups of dairy farms are presented.

Table 1. Income risk characteristics for dairy farms

SO	Farms	Income				Income loss (> 30%)				Indemnity	VaR 90%
	No.	avg.	min.	max.	SD	avg.	min.	max.	SD	(70% of total)	avg.
1,000 €		1,000 €				%				€	€
4	11	0.4	-0.4	1.1	0.4	26.8	13.4	60.7	13.5	784	803
8	105	1.1	-0.7	2.9	0.8	22.4	8.1	57.2	9.5	11535	1777
15	548	1.9	-1.0	5.7	1.3	23.2	9.1	52.7	8.6	137649	3192
25	1,210	3.2	-2.1	8.4	2.0	23.8	9.5	53.1	8.1	546098	5329
50	2,248	5.9	-4.4	25.8	3.6	23.7	7.3	57.7	7.5	1941991	10068
100	1,328	12.5	-3.2	53.5	6.3	22.8	5.3	47.2	6.7	2287114	20735
250	435	28.0	-3.9	71.4	13.9	22.0	11.6	45.5	6.3	1293260	45506
500	18	62.5	9.3	97.7	22.8	21.2	13.0	36.5	6.4	129498	100749
750	2	131.5	124.4	138.6	10.1	18.9	18.6	19.1	0.4	0	205264
3000	3	515.0	421.4	565.7	81.2	17.3	15.3	19.3	2.0	0	759305

As it could be noticed from Table 1 in all groups of farms, relatively large variation in income within groups is observed. This especially holds for groups with lower SO, where variation between farms is larger. The main part in the sample present farms with SO between 25,000 € and 100,000 €. As it could be observed from table 1 in most groups of farms, losses of income greater than 30% (regarding the current prepositions) occur only between 17.3 and 26.8% of states of nature. So probabilities are relatively low, especially regarding to other analysed sectors not presented in this paper. Of course this is average per group. Higher volatility is observed within groups, particularly those with lower SO. However it is apparent from the Table 1 that extremely low probabilities occur in the last two groups.

By testing developed approach we have estimated also hypothetical indemnities. In the case that income loss is greater than 30% of average income, 70% of producer total income loss is compensated. Calculated indemnity in Table 1 presents sum for all farms in a group. For each particular agricultural holding all possible states of nature (10,000) imitating possible situations are considered. We presumed that only probabilities with occurrence higher than 20% are considered. This means that we are interesting when trigger for indemnities is reached in each particular state of nature. In 80% of them indemnity would be equal or lower. As it is apparent from Table 1 for last two groups such losses occur on max with probability 19.3% and therefore no indemnities are in place.

Indemnities presented in Table 1 are calculated per group of farms and within a sector. However, it could be expected that total indemnities will be lower than calculated per groups as well as per sector (approx. 6,3 million €). This holds especially if we consider that in analysed case no condition was set when farms could participate in such a scheme. Total indemnity obtained assumes that all farms experiencing income loss greater than 30% would participate, regardless of their average income. This is definitely not the case in practice. If we increase minimum level of income as one of possible parameters that influence farmer's decision, total indemnity rapidly decreases.

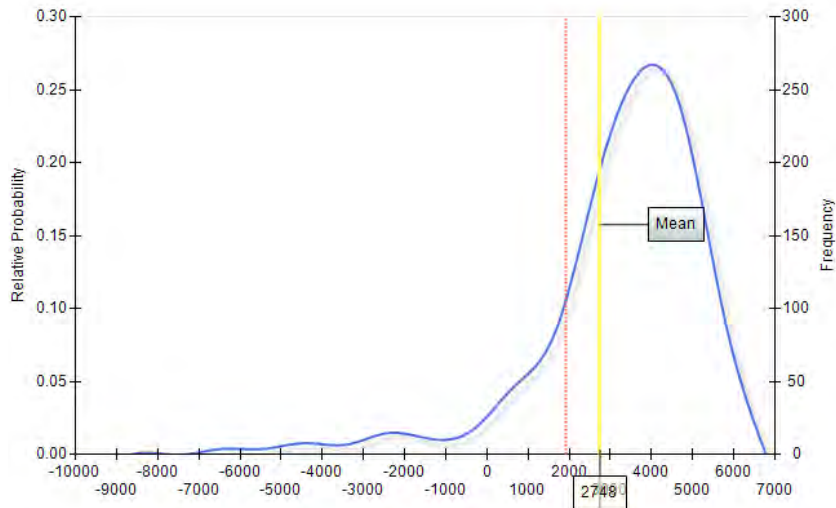


Figure 1. Frequency chart presenting mean income and threshold level for income losses greater than 30%

Figure 1 presents frequency chart for a selected agricultural holding from a sample of dairy farms. Resulted fluctuation exhibit a typical asymmetric feature, where frequent variations around the mean are interrupted by occasional spikes in the tail of distribution. This is due to the fact that some extreme negative occasions might occur with significant positive correlation. Similar pattern could be observed in most analysed examples.

4. Discussion and conclusions

The focus of this study was to present conceptual approach of systematic income risk analysis for different groups of agricultural holdings in a region with bottom up approach. Complex simulation model is applied to analyse individual farm risk income situation with respect to production plan information, based on subsidy applications. Applied approach proves useful, since with simulations and analysing the results one can better understand income issues at the farm group or sector level.

Developed tool has several limitations. Approach how standard outputs and gross margins per activities and per agricultural holdings were estimated is the critical component at the moment. In further development it is necessary to put more focus in this part. Where possible it is necessary to include additional information from other available data sources at micro level. FADN data per different groups and types of farms could be analysed and information could be included

as calibration index in the tool. In such a manner for different groups of agricultural holdings as well as for activities more precise random distributions could be defined. In further research also more stress should be put to define more sophisticated distributions for uncertain variables in the model. Where microeconomic data would be available, they should be included through empirical distributions. For other uncertain variables more attention should be put to define more sophisticated functions of random distributions.

Described approach could give enough reliable rough estimate of income risk at a group of agricultural holdings (e.g. sector level, group of agricultural holdings with similar economic size etc.). It seems that with further suggested developments this could be promising holistic approach to give additional information about income risk exposure at the farm level.

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