

## ESTIMATING INCOME RISK AT THE PIG SECTOR LEVEL<sup>1</sup>

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**A b s t r a c t.** The paper presents a possible theoretical approach how income risk could be indirectly analysed at the sector level. This is an important step in the early development stage of eventual policies dealing with income issues. In such circumstances one should have reliable information about the characteristics of income risk faced by different groups of farms in relation to their economic size and income structure. From an information viewpoint this is very demanding and is lack of information that is often the main obstacle for such preliminary analysis. The main assumption in the approach presented is that appropriate accounting data at the farm level are not available, as the most common approach to estimate income variability per farm. The approach presented utilises different sources of information, such as data at the farm level, national statistics and analytical models, in order to support the simulation process and to give greater insight into income losses at the sector level. The annual subsidy application is crucial information for each farm in the sector from which information about the main production activities could be gathered. On this basis, and with the support of other data sources, income structure for each farm analysed is reconstructed. To imitate income risk, potential from Monte Carlo Simulations is utilised. Possible different risks are entered as uncertain variables and are supported by different uncertain distributions, representing possible states of nature. In the current development stage they are mainly based on triangular random distributions. In such a manner income risk is simulated at the farm level; however results are summarised and presented for group of farms. Regarding this assumption, it is an example of a bottom-up approach. The tool developed is tested on data from the pig sector in Slovenia. The subsequent results suggest that this could be a useful approach for rough estimation of income risk and points out some limitations and drawbacks that could be further improved.

### INTRODUCTION

Income risk is becoming an important issue in agriculture, especially in those sectors in which market liberalisation has had a significant influence. The pig breeding sector in Slovenia is definitely one of such sectors that additionally seems to be in permanent financial crisis. By setting new agricultural policies or measures to support such farms it is therefore considerably important to follow also income stability as an indicator of the production

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conditions under which the farms operate. This means that it influences efficiency and stability of farms' production and also their capability to stay in business as well as their potential for further growth and development. Therefore it is important to have reliable information about the production conditions under which agricultural holdings operate. This is especially true for policy makers as important stakeholders of agricultural business.

Analysing income risk is from an information viewpoint very demanding. In many countries the desire to make in-depth income risk analysis hits on the problem of insufficient data sets for this purpose, especially for analyses of an holistic income risk management approach. Lack of fact-based knowledge about risk at the individual agricultural holding level could also be a significant problem in changing agricultural policies where risk management is becoming an important issue. Namely, risk assessment is a necessary first step to develop a good risk management strategy or tool [*Managing Risk...* 2011].

To follow trends and magnitude of income risk at the sector level, holistic analysis is needed. Already from the definition of risk it follows that we are interested in deviations from expected values, distributions of variables etc., which means that enough long data series are required. A common approach for such analysis is to use very accurate accounting data linked with other databases with enough long data series [Anton et al. 2011]. In the literature one can find many examples of how FADN data could be applied to analyse income risk and efficiency of income risk management as well as to make different studies to support policy makers. Such examples are Vrolijk and Poppe [2008], Severini and Cortignani [2011], *Managing Risk...* [2011], Majewski et al. [2007]. However, such holistic analysis is a big challenge if such on-farm accounting data are not available, or if the data quality is doubtful, which is quite a common occurrence in agriculture.

Our paper presents a possible theoretical simulation approach into how analyses of income risk at the sector level could be conducted without appropriate microeconomic data for each farm. The main idea is that we apply other sources of information available to policy makers. The crucial assumption is that we have some information of the actual production structure at the farm level and some information of income distributions based on national data sets and expert judgements. The aim of this approach is to get a rough estimation of income risk of the whole sector, or different groups of farms (e.g. merged through different economic size classes) and to estimate the magnitude of possible indemnities to compensate income losses. Beside a different methodological concept we are mainly interested in analysing characteristics of income risk. Through basic statistics, such as measures of central tendency and variation in relation to confidence intervals, risk measures and quintile measures, better insight into the analysed problem is provided. However, it has to be noted that the individual risk environment faced by a particular agricultural holding can significantly differ from sectorial or aggregate risk [*Managing Risk...* 2011, Kobzar 2006]. Consequently, the proposed approach is not appropriate for in-depth analysis of income risk for particular agricultural holdings.

The core methodology applied is based on Monte Carlo simulations (MCS) that have already proved to be a powerful method for conducting quantitative risk analysis. An approach of random sampling is especially beneficial when there are several sources of uncertainty that interact in the calculated outcome – income in our example. The principal idea is that uncertain variables, represented by 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 the literature one could find numerous examples how the 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 the MCS method in a static simulation model to estimate the level of volatility of farm incomes on six most frequent production types 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 this study is to present a theoretical approach about how income risk could be analysed without accurate accounting information, on different levels of agricultural sector. The paper presents the development of a preliminary attempt to assess the soundness and applicability of the proposed simulation tool. It has been tested on Slovenian pig breeding sector, to consider its strengths and weaknesses and to identify further improvements needed. The paper continues with a description of an applied approach and developed simulation tool, which is followed by an in-depth description of setting uncertain variables as well as basic characteristics of the data-base. We conclude with the results obtained and a short discussion.

## MATERIAL AND METHODS

### DATABASE

The main information for a particular agricultural holding's characteristic (physical production) are annual data delivered from subsidy applications (IACS) collected by the Slovenian Payment Agency. For the purpose of this study we considered data for CAP 1<sup>st</sup> pillar payments and also for Less Favoured Areas payments (LFA). The main benefit of this database is that we can analyse all farms applying for subsidies regardless of whether they practice accounting or not. Consequently almost all agricultural holdings in the sector could be analysed.

From the IACS database it is possible to gather information about the physical production structure for each particular agricultural holding in given period. With the current tool we considered data for the 'subsidy' years 2010 and 2011. The principal assumption was that production remains fixed and that farmers cannot add additional activity into the production plan in a particular year (state of nature).

In this way we got some information about all agricultural holdings in a particular agricultural sector, although without necessary the accounting data needed for proper analysis of income risk. This is also the main disadvantage of an applied approach. Therefore it was the main challenge, besides estimating achieved revenues, gross margins and incomes for each agricultural holding, to encapsulate income risk. Further we present a possible conceptual approach about how different data sources could be merged to mitigate this challenge.

In the first step standard outputs (SO<sup>2</sup>) for all activities included in the model have been calculated. For this purpose we considered values already calculated from another study utilising the same source of data [Rednak 2012]. SO for each activity was calculated based on the average data for the period 2005-2009, derived from internal data sources prepared by the Agricultural Institute of Slovenia. Further SO at the level of agricultural holdings has been calculated based on the methodology proposed by the European Commission [Rednak 2012].

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<sup>2</sup> The standard output of agricultural production means the monetary value of output corresponding to the average situation (average values over a reference period).

The database includes 59,632 agricultural holdings further divided into 22 farm types. For the purpose of this study and to demonstrate the approach developed we focus just on pig breeding farms. In this group 495 agricultural holdings have been identified. These farms are further divided into 13 economic classes that are determined in regard to the whole farm SO achieved.

The main disadvantage of this approach for risk analysis is of course that for all farms analysed 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 that has been adjusted for crop activities. In this case we have considered that the total arable land of an agricultural holding influences the efficiency of production. Smaller plots of arable land per farm (smaller than the average national production significant for a particular sector) result also in lower SO and vice versa. In both examples five different indices were considered, ranging from -20% to +20%.

To get the total average revenues per agricultural holding, 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 for each activity. This share has been denoted on an historical data set prepared by analytical Model calculations [*Model calculations...* 2013].

#### DEVELOPED TOOL AND SIMULATION MODEL

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

A simulation tool has been developed on a spreadsheet platform using MS Excel and Visual Basic. To run simulations, an 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. The simulation is performed based on MCS that are often applied for studying different systems involving uncertainty. It relies on random sampling of values for the specified uncertain variables included in the simulation model, based on Latin Hypercube sampling.

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

Regarding the fact that this is a preliminary version of the tool and to keep it simple at this development stage, for all uncertain variables addressing farming activities, a common triangular uncertain distribution is considered. It is defined by minimum ( $X$ ), maximum ( $Z$ ) and most likely ( $y$ ) values. A set of deflated historical data [*Model calculations...* 2013] was analysed to determine how SOs and variable costs for each activity change with time.

A simulation model simulating achieved income ( $I$ ) for each agricultural holding ( $f$ ) in different states of nature ( $j$ ), could be defined as follows:

$$I_j = GM_j - FC * g_f$$

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

$$GM_{ij} = SO_i e_i a_{ij} - SO_i * P * b_{issj}$$

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

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

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

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

where  $FC_j$  is presumed to be fixed without change in different states of nature. However, special calibrating coefficients  $g_f$  are added to the adjusted fixed costs regarding the size of total tillage area.  $GM_j$  represents the total gross margin achieved at the level of agricultural holding, which is the sum of all  $n$  activities' gross margins  $GM_{ij}$  that an 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 the simulation process.  $a_{is}$  is an index generated from a triangular distribution to adjust  $SO_p$  of activity  $i$ , for each state of nature  $j$  in respect to the selected scenario  $s$ .  $e_i$  is a static coefficient to adjust average  $SO_i$  of an activity to particular farm characteristics (e.g. crop – corn production). Variable cost is calculated as a percentage  $P$  share of  $SO_i$  and  $g b_{issj}$  is an index generated from a triangular distribution to adjust variable cost for each state of nature, regarding the scenario selected ( $s$ ).

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

The first scenarios in both cases include 'normal risk' or most likely deviations. This means that minimum and maximum values are in the range for a 'normal' ten year period. The second scenario was defined only for SO and includes the greater possibilities of extremes (positive correlation between risks) from the 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 higher frequencies of very bad as well as very good outcomes. In most cases this means that the outcome (revenue – in our case expressed as SO) could also be zero or something close to zero, and less likely that the outcome would be something very good. Just vice versa holds in defining uncertain indices for variable costs. Which scenario is selected in a particular state of nature depends on a discrete uncertain variable, based on a binominal distribution.

In the proposed analysis simulation includes 5,000 states of nature, which means that outputs for each activity and agricultural holding was calculated for 5,000 randomly sampled values.

## RESULTS

The paper presents aggregated results for the pig sector. Table 1 summarizes the main characteristics of the farms analysed and an insight into income risk and eventual indemnities is given in Table 2. Since simulation always yields a whole range of possible outcomes, it is very important how the results are analysed and interpreted. In the tool developed in-depth analysis of this viewpoint is conducted. In the first step measures of the central tendencies as mean, median and mode for expected income are calculated. In both cases we present average results per group of farms and also average results per farm showing also the difference within and between groups.

In Table 1 we present the main characteristics of farms analysed, classified into the pig fattening sector. There are 495 farms that have been classified into 9 economic size classes (ESC), regarding achievement of annual SO at the farm level (ESU). As is apparent from Table 1 the majority of farms cultivate on average between 10.4 and 41 ha of tillage area, with SO between 50,000 and 250,000 €. However, relatively high CV shows also in high heterogeneity of groups from the viewpoint of cultivated land. Especially in ESC 7, 8 and 9, there are some farms with very little or no tillage area. In these cases, feed needs to be purchased on the market and consequentially conditions from the arable sector are transposed into this sector. As it is apparent from Table 1, estimated average incomes are relatively low for all groups of farms. 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. From Table 1 it is apparent that, except in the last group (ESC 9), all groups contain farms with negative average income. High CV of income, which is lower in higher economic size classes, shows on a big difference between achieved average incomes per farm within the group. Average income plays a significant role in estimating income losses and also eventual compensa-

Table 1. Basic characteristics of analysed pig farms

| ESU     |     | ESC | Farms | Cultivated land |      | Income |       |       |      | ECO 0 + LFA |      |
|---------|-----|-----|-------|-----------------|------|--------|-------|-------|------|-------------|------|
| 1,000 € |     |     |       | avg             | CV   | avg    | min.  | max.  | CV   | avg         | CV   |
| From    | to  | no. | ha    | 1,000 €         |      |        |       | €     | %    |             |      |
| 0       | 2   | 1   | 7     | 0.58            | 0.61 | 0.07   | -0.01 | 0.17  | 0.93 | 181         | 63.5 |
| 2       | 4   | 2   | 16    | 0.91            | 0.48 | 0.08   | -0.13 | 0.40  | 1.92 | 278         | 70.1 |
| 4       | 8   | 3   | 31    | 1.98            | 0.34 | 0.20   | -0.64 | 0.66  | 1.31 | 681         | 45.1 |
| 8       | 15  | 4   | 55    | 3.93            | 0.33 | 0.61   | -0.55 | 1.43  | 0.67 | 1469        | 36.9 |
| 15      | 25  | 5   | 71    | 6.18            | 0.26 | 1.20   | -1.12 | 2.79  | 0.70 | 2219        | 32.0 |
| 25      | 50  | 6   | 154   | 10.38           | 0.36 | 3.32   | -1.79 | 10.75 | 0.69 | 3856        | 42.1 |
| 50      | 100 | 7   | 114   | 17.81           | 0.39 | 6.15   | -1.96 | 14.70 | 0.61 | 6459        | 42.6 |
| 100     | 250 | 8   | 43    | 41.04           | 0.48 | 16.57  | -7.53 | 40.72 | 0.68 | 15325       | 55.9 |
| 250     | 500 | 9   | 4     | 97.49           | 0.48 | 51.06  | 13.79 | 94.13 | 0.65 | 44358       | 56.7 |

Source: own study.

tion, presented in Table 2. In this regard one should also consider CAP measures from the first and the second pillar. Thus, more detailed analyses shows a significant influence of subsidies (ECO 0 and LFA) on incomes that are closely related to tillage area. Even though there are big differences (CV) between farms regarding acquired subsidies, it is apparent that on average the sum of subsidies per farm is greater than the average income achieved per farm. This shows in two phenomena typical for this sector. The first is the problem of permanent crises of the sector in Slovenia (very low incomes), with downstream effects due to high variable costs and low pig meat prices. And the second is that high payments per arable land, which is supposed to change after the current CAP reform. However, at the moment in some cases they have an important income stabilising effect and income risk is thereby reduced.

The main aim of the presented toll is to estimate and to analyse income risk. In this regard we have analysed the probability of income losses and eventual indemnities paid to farmers. We considered the WTO rule, which assumes that eventual income loss could be compensated for only if the loss is greater than 30 % of the average income and in such a case the indemnity can be up to 70 % of the total income lost. Calculated indemnities (Tab. 2) present the sum for all farms in a group. In modelling for each particular agricultural holding all possible states of nature (5,000) imitating possible situations are considered. However, we presumed that only probabilities with occurrence higher than 20% are considered. This means that we are interested when a threshold for indemnities is reached in each particular state of nature. In 80 % of cases indemnities would equal or be lower than the calculated sum. As it could be noticed from Table 2, the average frequencies are relatively high, ranging from 33.21 up to 43.22, while lower average frequencies are typical for higher ESC, where also slightly greater differences between farms within the group are observed. This definitely shows the high riskiness of this sector, especially in regard to other analysed sectors not presented in this paper.

Indemnities presented in Table 2 are calculated per group of farms within a pig sector. However, it could be expected that total indemnities will be lower than calculated per group as well as per sector (approx. 1.04 million €). This holds especially if we consider that in

Table 2. Income losses and indemnities per group of farms and per farm

| ESC | Income loss for more than 30% |       |       |      | Entitled farms | Indemnity total | Indemnity per farm |        |        |      |
|-----|-------------------------------|-------|-------|------|----------------|-----------------|--------------------|--------|--------|------|
|     | avg                           | min.  | max.  | CV   |                |                 | avg                | min.   | max.   | CV   |
|     | %                             |       |       |      |                |                 | %                  | €      | €      |      |
| 1   | 41.99                         | 35.34 | 51.04 | 0.15 | 71             | 374             | 68                 | 14     | 109    | 0.47 |
| 2   | 43.22                         | 30.90 | 52.86 | 0.15 | 69             | 1,529           | 142                | 104    | 202    | 0.20 |
| 3   | 41.74                         | 29.26 | 63.18 | 0.16 | 77             | 6,358           | 276                | 152    | 505    | 0.30 |
| 4   | 38.73                         | 29.48 | 53.86 | 0.12 | 96             | 25,840          | 494                | 319    | 714    | 0.20 |
| 5   | 38.30                         | 24.10 | 54.20 | 0.16 | 93             | 60,245          | 942                | 618    | 1,712  | 0.27 |
| 6   | 35.01                         | 18.18 | 54.28 | 0.22 | 90             | 241,342         | 1,780              | 0      | 3,271  | 0.31 |
| 7   | 35.33                         | 21.20 | 50.34 | 0.21 | 92             | 353,355         | 3,494              | 2,132  | 6,662  | 0.27 |
| 8   | 33.21                         | 17.22 | 51.22 | 0.25 | 88             | 279,799         | 7,500              | 0      | 15,461 | 0.38 |
| 9   | 30.68                         | 24.74 | 41.22 | 0.24 | 100            | 71,485          | 17,871             | 12,630 | 25,896 | 0.33 |

Source: own study.

the analysed case the only condition when farms participate in such a scheme was when average income is at least zero. Total indemnity obtained assumes that all farms fulfilling this condition and experiencing income loss greater than 30% would participate and from Table 2 it is apparent that a high proportion of farms fulfil this condition (in total almost 90% of farms). This is definitely not the case in practice, namely much less farms would participate. If we increase the minimum level of average income, as one of the possible parameters that influence a farmer's decision to participate or not, the total indemnity rapidly decreases. In the case that condition is set to an average income of 12,000 €, total indemnities decrease down to 0.585 million €, representing only 10 % of entitled farmers. In Table 2 also information on indemnities per farm are presented. Those would range between a few cents up to 25,896 € or an average between 68 and 17,630 €.

## DISCUSSION AND CONCLUSIONS

The focus of this study was to present a conceptual approach of systematic income risk analysis for different groups of agricultural holdings specialised in pig production with a bottom-up approach. A complex simulation model is applied to analyse the individual farm risk income situation with respect to information of a production plan, based on subsidy applications. This applied approach proves useful, since with simulations and analysing the results one can better understand income issues at the sector level and also get some information about the eventual magnitude of potential indemnities.

The approach described could give a sufficiently reliable first estimate of income risk for a group of agricultural holdings (e.g. sector level, group of agricultural holdings with similar economic size etc.). It seems that with further developments this could be a promising holistic approach to give additional information about income risk exposure at the farm level. Policy makers, as one of relatively important farmers' stakeholders, could get some basic information about what is going on in a particular sector.

Due to the applied approach of utilising only information from subsidy applications it is expected that the tool developed has several limitations for income risk analyses. In this regard how standard outputs and gross margins per activities and per agricultural holding were estimated are the most critical components. In further development it will be necessary to put more focus on this part. Where possible it is necessary to include additional information from other available data sources at the micro level. FADN data for different groups and types of farms could be analysed and information could be included as a calibration index. In such a manner for different groups of agricultural holdings as well as for activities more precise random distributions could be defined. 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.

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#### SZACOWANIE RYZYKA DOCHODOWEGO DLA SEKTORA TRZODY CHLEWNEJ

##### Streszczenie

Zaprezentowano podejście teoretyczne dotyczące sposobu analizy pośredniej ryzyka dochodowego na poziomie sektora. Przedstawione podejście wykorzystuje różne źródła informacji, takie jak: dane na poziomie gospodarstwa, statystyki krajowe i modele analityczne, które mają pomagać w prowadzeniu prawidłowej symulacji i dawać lepszy wgląd w straty w dochodach na poziomie sektora. Kluczową informacją z każdego gospodarstwa w sektorze jest aplikacja rocznych dotacji, na podstawie której udało się zgromadzić informacje dotyczące głównych działań produkcyjnych. Na tej podstawie, a także poprzez potwierdzenie innych źródeł danych, zrekonstruowano strukturę dochodów każdego analizowanego gospodarstwa. Do symulacji ryzyka dochodowego wykorzystano metodę Monte Carlo. Ryzyko dochodowe jest symulowane na poziomie gospodarstwa, jednak wyniki przedstawione są dla grupy gospodarstw. Jest to przykład podejścia oddolnego. Symulacji dokonano wykorzystując dane sektora trzody chlewnej w Słowenii. Uzyskane wyniki sugerują, że może to być przydatne podejście do szacowania ryzyka dochodowego i wskazują na pewne ograniczenia i wady, które mogą być dalej poprawiane.

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