Index-based Costs of Agricultural Production (INCAP) – A new cost and risk analysis tool

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Abstract

Producers of agricultural commodities are exposed to numerous uncertainties regarding output and input prices, crop yields, yield responses to inputs and the like. In agricultural risk analyses, relevant developments or events are usually measured in economic terms resulting in a positive or negative impact on farm incomes. We develop a novel data set: the 'Index-based Costs of Agricultural Production' (INCAP) that can be used to quantify risk-related statistics associated with standardised production systems. Activity-specific gross margins and their stochasticity can be measured at an arbitrary level of aggregation. The aims of this article are to present the structure and scope of INCAP and to demonstrate its potential use in agribusiness, farm extension programmes and policy analyses. Wheat production in Austria is presented as an example.

Keywords INCAP, agricultural production costs, economic modelling, risk analysis, Austria

JEL code Q10, Q12, Q13, Q18, Q54

1 Introduction

The agricultural sector is exposed to numerous uncertainties regarding different aspects, e.g. market and prices, production, equipment, financing and labour (see e.g. Hambrusch et al., 2015). In farm economics, risk-related events or developments are usually measured in economic terms resulting in a positive or negative impact on activity-specific gross margins, farm-specific incomes or incomes at the sector level. Information on risk and the stochasticity of economic variables is essential in order to understand the behaviour of agents in the market and of contractual arrangements in the value chain.

In most economic models of agriculture, production costs are an essential element. Some models estimate them assuming specific technologies and/or functional forms using observed data. Others, such as linear or positive mathematical programming models, use average production costs which are often based on gross margin calculations developed for extension services. Such cost data are usually available for the past and for specific settings, like regions or observed farm sizes, but rarely for scenarios that make projections into the future and/or that need to change underlying settings. To overcome this gap, a new set of data called 'Index-based Costs of Agricultural Production' (INCAP) has been developed.

INCAP is a detailed data set on production costs in agriculture. In its current state it is specific to Austria but the method is not country-specific and data for other countries in temperate zones can be easily developed using this approach. INCAP accounts not only for a wide variety of relevant activities (e.g. production of quality wheat) combined with specific attributes (e.g. certain management variants), but it is also established as a time series from 2005 to 2013 and is designed to allow future scenarios until 2050. With its focus on the micro-economic level, costs are specified per unit of output. INCAP is based on a range of existing data repositories that describe agricultural production systems in a detailed manner. Its contribution to the knowledge base is to explicitly represent management variants, various production options and time. The aim is to capture the heterogeneity of agricultural production in a country or region and the production costs of typical farms.

In this paper, INCAP is introduced by presenting its development, structure, scope and possible applications (chapter 2), followed by a description of data sources used and adaptations made (chapter 3). The example of quality wheat is used to demonstrate some of the features of the data set (chapter 4). The issue of validating INCAP is addressed in chapter 5. The paper concludes with a summary, discussion and an outlook on future developments (chapter 6).

2 Development, structure, scope, potential applications

2.1 Development process

Agro-economic models require technical (e.g. input quantities, yields, technology used) and economic information (e.g. input and output prices, agricultural payments). The respective data and literature are made available by numerous organisations, including public agencies, research institutes, interest groups and non-profit organisations. When developing a new data set, it is often more practical and cost-efficient to adapt existing data to the research task than to start from scratch. As for INCAP, dimensions were added to existing information and developed further, in particular regarding management variants and time.

The development process was structured in the following way:

(a) definition of INCAP's scope and structure;
(b) exploration of existing data sets for relevance for and compatibility with INCAP;

(c) selection of existing data sets and fitting them into INCAP's structure;
(d) identification of alternative sources in case of missing data;
(e) replacement of explicit data by functions whenever possible to allow swift updates.

In order to improve its reliability, INCAP is

(f) subject to a series of checks and sensitivity analyses;
(g) validated against other sources and scrutinised by experts;
(h) if necessary, revised to improve data quality and thus the quality of model results based on these data.

2.2 Structure and scope

Due to differing attributes and cost items (as described below), INCAP is divided into plant and livestock production **activities**:

- **Plant production (INCAP.p):** INCAP.p covers crops (arable crops, feed, permanent crops), forage (silage, hay, grazing), fruit and vegetables. These activities are constrained to certain land types (arable land; permanent cropland; permanent grassland). For instance, the activity 'quality wheat' is assigned the land type 'arable land', as it can only be produced on arable land.
- **Livestock production (INCAP.l):** The activities represented in INCAP.l include meat, milk, eggs, wool and breeding animals. These activities were chosen in order to cover a large share of the output of the agricultural sector in Austria.

Each activity in INCAP comprises the three **dimensions** attributes, cost items and time:

- **Attributes:** To reflect the heterogeneity in production conditions and management variants. The numeric level of certain cost items is differentiated by attributes that belong to certain attribute groups. For instance, the attribute group 'farming system' consists of the attributes 'conventional' and 'organic'. Some attribute groups are applicable to both INCAP.p and INCAP.l (e.g. farming system), whereas others are specific to plant activities (e.g. tillage system).

  In INCAP.p, the attribute groups (and attributes) are field size (number of hectares, continuously adjustable), farming system (conventional; organic), tillage system (standard; conservation), labour type (own labour only; own and hired labour), climate type (dry; humid) and plant protection intensity (high; medium; low).
- **Cost items:** Similar to the attribute groups, the cost items considered for plant and animal activities differ from one another. INCAP.p accounts for variable costs of seeds/propagating material, fertiliser, plant protection, machinery, crop insurance and other (e.g. cleaning, drying, storage). In INCAP.l, specific cost items include stock replacement, feed and veterinary services.
- **Time:** The baseline data set is established for the reference period, i.e. the annual average of 2011 to 2013. To generate data for specific years, price indices are applied to each cost item in the reference period. The indices stretch from the past (year 2005, e.g. agricultural price index) to the future (the current time horizon ends 2050).

The **high degree of differentiation** resulting from the combination of activities with attributes, cost items and the time dimension is noteworthy: For instance, combining 30 plant production activities with the attributes mentioned (two different field sizes, two farming systems, two tillage systems, two labour types, two climate types, three plant protection intensities) gives 2,880 unique combinations in a single period. By adding the time dimension, the data set comprises several thousand cost estimates. At present, some activity-attribute-combinations are technically or economically not meaningful (e.g. the activity 'hybrid maize' combined with the attribute 'organic farming' or the combination 'spelt, conventional farming') and are thus removed from INCAP.

2.3 Potential applications and adaptation to the research question

INCAP provides a comprehensive data set which can be used for a wide variety of analyses. **Potential applications** include, but are not limited to, questions concerning:

- farm business strategy (e.g. identify the cost-minimising or gross margin-maximising activity mix; identify the upper limit for payable land rent for future business years);
- risk analyses (e.g. identify the income foregone due to a price decline or extreme weather conditions);
- policy analyses (e.g. identify activity mix with minimum amount of greenhouse gas emissions or maximum amount of consumable calories);
- regional analyses (e.g. compare activity mixes and economic indicators of different regions);
- changes over time.

It is likely that INCAP needs to be **adjusted to the focus of the analysis,** by adapting the list of activities available, the attribute groups or attributes available, the activity-attribute combinations allowed, the cost items considered, the numeric level of economic or physical coefficients, the periods considered or the indices imposed on cost items; by adding further dimensions (e.g. 'area', 'agricultural policy') etc.

One aspect particularly important in risk and environmental analyses is the regional dimension. In **spatially-explicit analyses,** activities are constrained to geographic areas with suitable production conditions. The areal dimension is currently *not* considered in INCAP, yet INCAP can be adjusted to facilitate such analyses. To this end, it is necessary to:

(a) add the dimension 'area': by defining an exhaustive list of all regions considered;
(b) define the activity-attribute-area combinations allowed: by assigning site- and region-specific characteristics, out of the pre-defined INCAP attributes (e.g. 'humid' or 'dry'), to each of these regions;
(c) make data specifications for the activity-attribute-area combinations allowed (yield and, if applicable, other aspects which are differentiated by region, e.g. number of work cycles, producer price).
(d) Region-specific analyses can be taken one step further by examining **changes over time.** For instance, grape cultivation is limited to the eastern part of Austria in the baseline scenario. In a climate change scenario, the areal constraint is relaxed to allow grape cultivation in other parts of the country as well. In this case, the activities allowed, the characteristics of the regions examined as well as the numeric level of costs (through the imposed indices) vary over time.

Considering the range of possible applications, INCAP is of interest for various **user groups** such as farm business managers, extension services, agricultural or environmental economists, policy analysts and others.

3 Data sources, adaptations and updates

INCAP is mainly derived from **existing data repositories.** A series of sources was reviewed with respect to their suitability for INCAP in terms of cost items, their differentiation by attributes and time reference (see Heinschink et al., s.a.). Of all sources reviewed, a data set called 'Internet gross margins and data' (hereafter referred to as 'Internet-GM'; see AWI, 2015) was chosen as the principal source for INCAP since it meets most requirements: the data are Austria-specific and mostly based on published data (e.g. output prices, standard values for machinery costs; provided by public agencies), on functional relations (e.g. nutritional requirements for livestock), but also on unpublished data (e.g. input prices and typical input quantities; collected from suppliers). Internet-GM is updated periodically and publicly accessible through an online application, thus any user can individually revise INCAP by consistently referring to the principal source. The data set covers the majority of agricultural activities included in INCAP, thus entailing some consistency in the data generation across activities. The Internet-GM activities are differentiated by attribute groups (e.g. farming system, labour input) and the cost structure is suitable for INCAP.

To develop INCAP as aspired in the study, it was however necessary to make some **simplifications and assumptions.** Whereas the Internet-GM is an information system in which almost any parameter can be adjusted to arbitrary farm situations, such a level of detail is not necessarily helpful for the purpose of INCAP which is *not* to characterise any conceivable farm, but to capture the most important characteristics of typical farms.

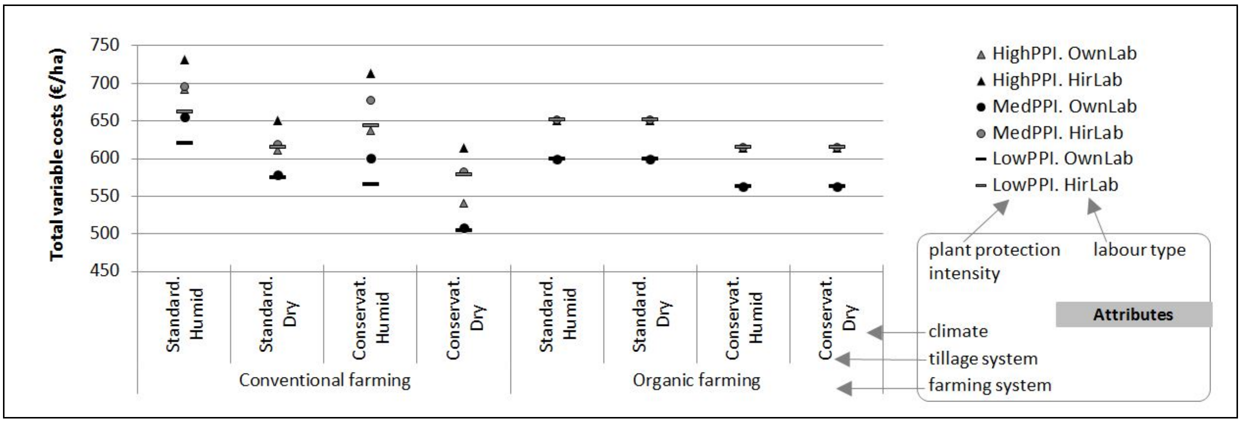
In addition, to achieve consistency and comparability of results, it is useful to **select a small number of representative scenarios.** Regarding the assumptions made, the data for INCAP was sourced from the corresponding Internet-GM activities using their default values. Firstly, the 'general assumptions' in the Internet-GM activity were adjusted to match INCAP's baseline scenario; this included crop quality, field size and period observed. Secondly, the required attributes were selected, and the default values reported back for these settings were then used for INCAP.

Another point worth noting is the **frequency of updates** of the Internet-GM. The vast amount of data compiled in the Internet-GM originates from different sources which are available at different – sometimes irregular – points in time. Hence the data in the Internet-GM are updated whenever new information is available; this does not happen in one go but is a continuous process throughout the year. Using the Internet-GM's **documentation** feature, each activity queried for INCAP was documented for later reference.

4 The example of quality wheat in two different Austrian production regions

Quality wheat for the reference period (2011-2013) is chosen as an example to demonstrate the usefulness of INCAP. Assuming an average yield of 4.75 t/ha, total variable costs of quality wheat range from €505 to €733/ha (see figure 1) depending on management and climate conditions. This result is explained by the fact that costs depend on the attributes listed above. Costs of seeds (€75-€98/ha), fertiliser (€191-€199/ha) and plant protection (€0-€142/ha) differ due to farming type; plant protection costs also vary based on the attribute plant protection intensity. Machinery costs (€176-€320/ha) are costs of machinery, repairs, fuel and – if a contractor is hired – also the labour costs charged for that work (e.g. harvesting); they depend on field size, farming system, tillage system and labour type. Insurance costs (€24/ha) are constant as they do not depend on any of the mentioned attributes. Likewise, drying costs (€9-€15/ha) are independent of attributes, but vary based on yield.

Figure 1: Total variable costs (€/ha) for 48 combinations of quality wheat production (no straw recovery, field size: 2ha, tax excl.) in the reference period (avg. 2011-2013).



Source: Own figure, 2015.

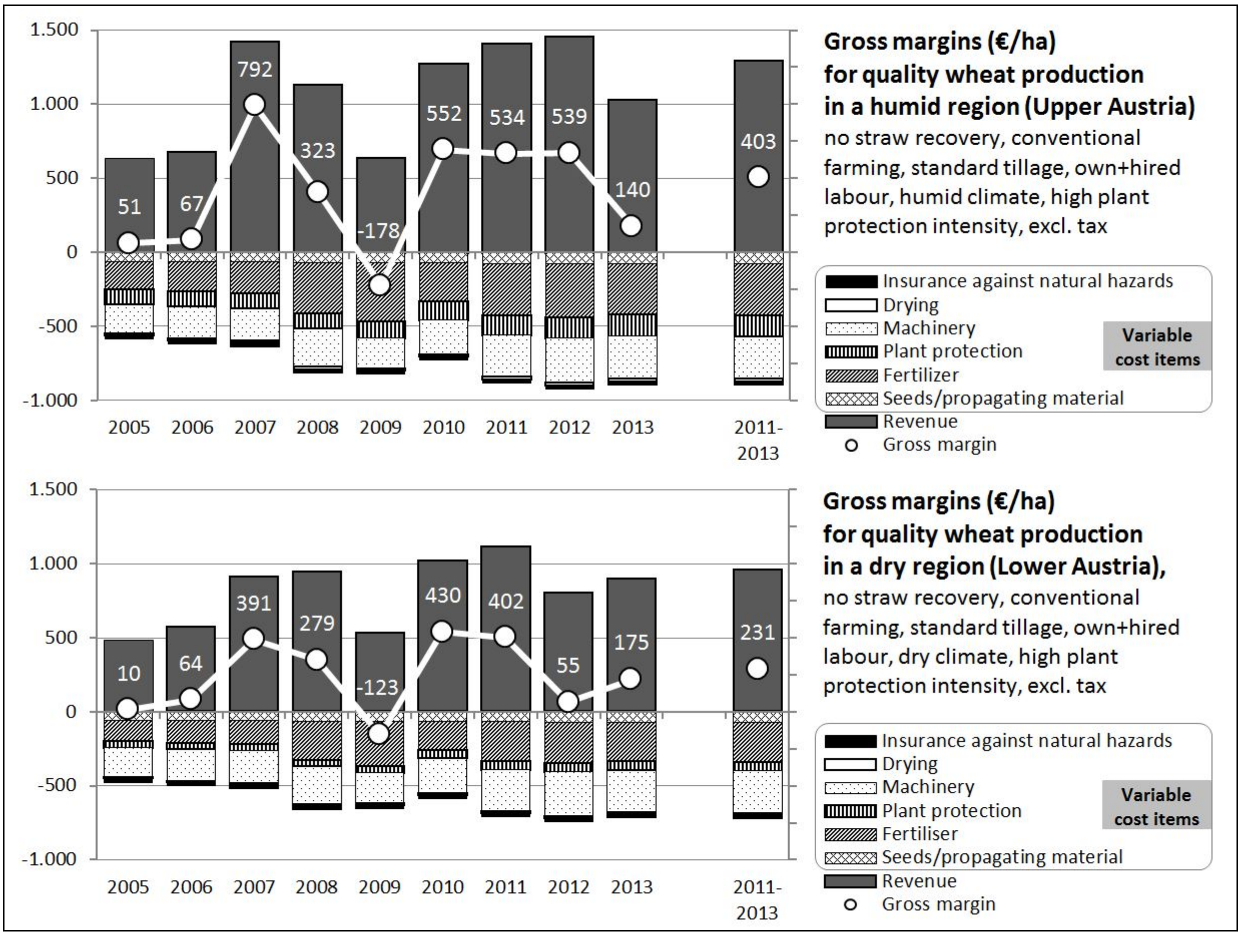
There are many purposes for differentiating production system of one crop in such a detailed manner. For spatially-explicit farm models, which are used to identify optimal management practices given various policy settings or preferences of farm decision makers, it is necessary to make the production variants explicit. Another purpose of detailed cost calculations is given in the administration of complex agricultural policies like the programme of rural development. Premiums for such measures must be fine-tuned to the situations of potential participants. To define premiums of agri-environmental measures like organic farming or tillage systems minimizing leakage of nutrients, it is necessary to quantify the impacts on the profitability of activities.

Figure 2 shows two wheat production activities to demonstrate a time series for both a humid and a dry region (Upper and Lower Austria, respectively). In both cases, yields as well as output and input price indices vary from 2005 to 2013.

The assumption was made that apart from yields, prices and costs, all other management characteristics remain unchanged. The production variant indicated by the small triangle labelled ‘conventional farming, standard, dry climate, high plant protection intensity, own+hired labour’ in Figure 1 is consistent with the time series of wheat production in the dry region in Figure 2.

In the case of the humid region, as shown in the top panel of Figure 2, revenues ranged from €636 to €1,457/ha, total variable costs from €585 to €918/ha and gross margins from –€178 to €792/ha over the selected period of time. The fluctuations in gross margins over time can be easily decomposed to the fluctuations of yields, output prices and respective cost items.

Figure 2: Gross margin (€/ha) time series for a quality wheat production in a humid region (Upper Austria) and a dry region (Lower Austria)



Source: Own figure.

5 Validation and revisions

A data set like INCAP will never be complete because agriculture is evolving and new crops, new activities, new practices are introduced continuously. Revisions may also be prompted by the focus of the particular research question (e.g. introducing new cost items, adding new attributes). Therefore, validation, plausibility checks and revisions are carried out throughout the process of developing INCAP which can be validated and revised regarding its structure, scope, data and functions used or results identified.

Various sources using different approaches are available for validating and revising INCAP (see e.g. Heinschink et al., s.a.: 5f)**:**

- **Planning data:** Two published sources comprising Austria-specific, average production costs by activity are currently available for the year 2007, i.e. the ‘Gross margins based on the Economic Accounts of Agriculture’ (‘EAA-GM’, see e.g. Sinabell et al., 2011; Strauss et al., 2012) and the ‘Standard gross margins’ (‘Standard-GM’) (BMLFUW, 2008).

  The approach and cost structure of the EAA-GM and INCAP are different. For instance, the EAA-GM use data at the national level (million euros) as the starting point to arrive at unit values (euros/ha). The results are hence not directly comparable to those of INCAP, yet the level of total production costs per unit (euros/ha) can be used for validation.

As the predecessor of the Internet-GM, the Standard-GM are characterised by a similar cost structure and differentiation of attributes for most of the relevant activities. At the time, this was one of the few published sources suitable for validation against INCAP.

- **Farm records:** Several groups of farmers with an interest in special branches of production (URL: http://www.arbeitskreisberatung.at/) are meeting regularly and record cost data on their farm. The purpose is to collect data that can be used for benchmarks and to learn from those peers who are performing best. Such data are evaluated in parallel to the development of INCAP in order to calculate indicators that can be used for validation of INCAP.
- **Observed farm data** like those from the Farm Accountancy Data Network (FADN; URL: http://ec.europa.eu/agriculture/rica/): Book keeping data from thousands of farms are used to measure farm incomes in the EU year by year. Detailed data from sample farms can be used to derive cost parameters using various methods (see e.g. Donati et al., 2013). Comparing INCAP results with results from econometric analyses or programming models is an option for validation in the future.
- **Functions:** As stated earlier, functions are used to replace explicit data in INCAP wherever possible in order to simplify INCAP and improve the reliability of its results. In some instances, functions may become available at a later stage where currently explicit data is used. The results generated by using these functions could be compared with the explicit data. Moreover, it may become necessary to revise the functions currently used for instance, due to technological progress or changes in common management practices. Such functions may be sourced from gross margin calculations, production guidelines, text books and many other references.

In a **first testing of INCAP.p,** INCAP's cost structure was compared with the structure of existing gross margin calculations. While it is possible to include additional items (e.g. variable costs of irrigation) at a later stage, the items currently included are the ones commonly used in gross margin calculations. Regarding the robustness of the preliminary results, selected INCAP activities were validated against other data sets. More validation and plausibility checks, which are likely to make revisions necessary, are planned for the future. Results of the validation will be discussed in more detail when the development of INCAP has progressed further.

6 Summary, discussion and conclusions

This paper presents INCAP (Index-based Costs of Agricultural Production), a new data management system used to explore costs of all important agricultural activities in Central Europe. INCAP's primary purpose is its use in farm and sector models for Austria. However, as demonstrated, it could also be used for many other tasks, such as activity-specific, farm-specific or sectoral risk analyses.

Based on existing data collections, INCAP contributes to the existing knowledge of costs in agriculture in several aspects. First, in accounting for a wide range of production conditions and management variants, the data allow to represent costs of almost any farm in almost any region in Austria. The data are therefore useful for both farm-specific analyses and aggregate spatially-explicit analyses. Second, the time dimension is accounted for and thus it is possible to generate consistent data sets for arbitrary base year periods and future years (e.g. for scenarios up to 2050). As shown in the literature, the cross-sectional and time dimensions of such data sets are very valuable in analysing uncertainty and risk in agricultural production systems. With minimal additional efforts, the data can also be used for farm-specific cost analyses when bookkeeping data are not available.

Besides these strengths, INCAP's limitations must also be taken into account. Constant farming technology (expressed as machinery costs per application and ha, or fixed labour coefficients) and methods (e.g. number of plant protection applications) were assumed throughout the timeframe in order to achieve consistency. These assumptions need to be adjusted in the future in order to examine the effects of technological change and labour saving mechanisation. In order to do this, further research is necessary to more accurately specify the relevant parameters.

Like the activity-attribute-(area-)combinations, the underlying assumptions need to be made explicit in the context of the research question. Given that technology is fixed, this implies that the data set can be used to analyse adaptations of currently existing systems to varying price conditions but only in a static manner. In order to represent technological shifts adequately, more research is necessary to track technical advances in a very detailed manner.

Most of the data are based on observations and are therefore empirically valid in a certain sense. Various cost items and the gross margins, however, depend on specific technology assumptions and experts' judgement. In order to improve INCAP's validity, it will be necessary to systematically compare INCAP with activity-specific costs observed on farms. Contrary to countries where such data exists (e.g. Switzerland), this cannot be accomplished for Austria at present since activity-specific cost accounting data are hardly available. Once detailed data of INCAP are published, a first step is taken to close this information gap. The work on INCAP may stimulate the discussion on the value of specific cost information and thus contribute to a better understanding of the specific agricultural situation in Austria.

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