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A Relatively Easy-Access Description of the Logistics, Purposes and Function of the Sector Model KRAM.

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Summary

This working paper describes the design of KRAM; a model of the Danish agricultural sector that has been developed in a research project at KVL between 1997 and 2000. The purpose of this paper is to give a general and non-technical overview of the model. The paper is directed at people who want a more detailed knowledge of the model, but without addressing the underlying formulas and programs.

The paper focuses on the logistics of the model. This includes how data are produced and utilized within the model and how the various submodels are designed and work together. Furthermore the calibration and solving procedures and the time aspects of the models are described. Some of these descriptions may appear somewhat interim due to the fact that the model itself was not fully operational when this paper was published.

Sammendrag

Dette working paper beskriver opbygningen af KRAM, der er en model for den danske landbrugssektor, konstrueret i et forskningsprojekt på KVL i perioden 1997-2000. Formålet med dette papir er at give et generelt og ikke-teknisk overblik over modellen, og retter sig mod personer der er interesseret i et nærmere kendskab til modellen uden at sætte sig ind i de bagvedliggende funktioner eller programmer.

Papiret fokuserer især på logistikken i modellen, herunder hvordan data produceres og anvendes internt i modellen og hvordan de forskellige submodeller er opbygget og arbejder sammen. Desuden beskrives kalibrerings og løsnings procedurer samt tidsaspektet i modellen. At modelbeskrivelsen visse steder har et foreløbigt præg skyldes, at modellen endnu ikke var køreklar ved dette papirs publicering.

1 Introduction

KRAM (KVL's Regional Agricultural Model) is a model of the Danish agricultural sector that is being developed to conduct analysis on the interactions between agricultural and environmental policy, markets, production and the environment. KRAM has been developed in a research project at KVL financed by the Danish Research Councils from 1997 to 1999. The present model design is new, but has been inspired by a number of earlier models, especially Day (1963), Bauer (1989), Helming (1997), Andersen et al. (1979) and Andersen et al. (1974). KRAM was first described by Wiborg (1998), and has later been described by Wiborg (1999). Currently, a detailed manual describing all functions and data is in press (Wiborg, 2000). The intention of this presentation is to provide the interested reader with a quite detailed description of the KRAM model, illustrating the purpose of the overall KRAM model and the individual submodels, the dynamic flow, how variable groups are moving within the submodels and an overview of the potential and limitations of the model. If a more detailed knowledge of KRAM is requested, we refer to the papers describing some of the submodels in great detail, or the KRAM manual mentioned above. A number of these papers are still being prepared, and will appear on the KRAM web page[1] as soon as they are ready.

KRAM consists of several submodels with very different structures, characteristics and scopes. But generally KRAM can be described as spatial, dynamic bottom-up model based on representative farm firm models. The optimisation criterion is maximisation of expected long-term profits. A three-period farm firm model structure is applied in order to describe the short-term dynamic relationships. The long-term development of the sector as a whole is also determined in the model by estimating the investments and the structural development.
These overall characteristics of KRAM enable detailed analysis of changed production possibilities on the farm level, extension of this analysis to estimate the regional environmental impact and the national economic effects and also determination of the long-term effects of different policy scenarios. KRAM can provide estimates on the effects of policy changes including:

- the economic effects for farmers
- the economic effects for the government
- changes in agricultural employment

[1] http://www.flec.kvl.dk/kram

- changes in the environmental impacts
- the spatial distribution of these variables (both geographically and between farm groups)
- the dynamic development of these variables

By conducting such policy analysis, KRAM can assist in decision making in relation to agricultural and environmental policy. The flow of the model is illustrated in Figure 1.

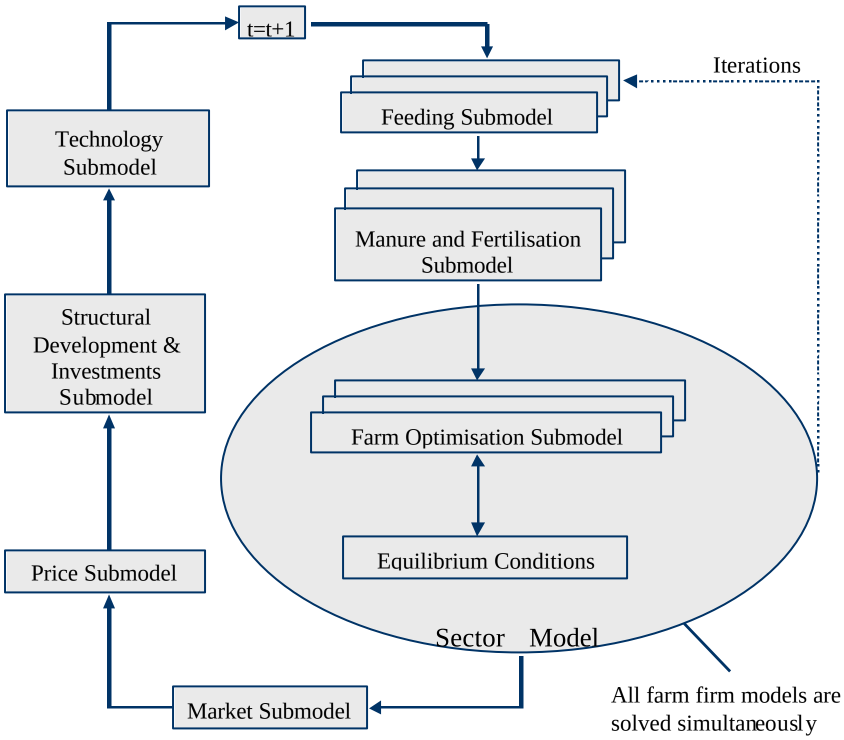

Figure 1. Graphical overview of the structure of KRAM

1.1 Definitions

Since profit maximising behaviour is assumed in the model only full time farmers have been included in KRAM. It has been assumed that part time farmers and hobby farms that are not making a living out of farming are not profit maximising. An example of the validity of this assumption is that in every year from 1993/94 – 1997/98 part time farmers' ratio of income outside of agriculture to the gross profit has ranged from 8.17 – 11.83 (SJI, 1994; SJFI, 1995; SJFI, 1996; SJFI, 1997; SJFI, 1998). This shows that part time farmers' primary income source is not agriculture, and therefore they cannot be assumed to put all their time in optimising the farm. The full time farmers must do so in order to survive, since there is no significant off-farm income for them to lean back on if the farm is not economically efficient. The cost of doing this is that the model must use exogenous forecasts about the production of the part time and hobby farms to be able to provide the full picture of the Danish agricultural production. The full time farmers' constitute 44% of the total number of farms, but they cultivate 74% of the total arable land and own 98% of the milking cows, 97% of the breeding pigs and 95% of other pigs (SJFI, 1998).

In KRAM the Danish agricultural sector is divided into 12 regions and 7 different production types, giving a total of 84 representative farm types, which multiplied by the number of farms in each group aggregates into the whole sector. These characteristics result in different versions of the feeding, manure and fertilisation and farm firm submodels for the different farm types, which in Figure 1 is indicated by the three layers of boxes for these submodels.

The division into regions is relevant due to differences in soil types and limitations to transport of manure etc. Each region, and thereby each farm type, is assumed to have only one soil type.

The different production types are arable farms, dairy cows, pork and versatile production, with the first three types further divided into two groups according to size measured by standard gross margins, giving a total of seven different production types.

The time periods used in KRAM are one year periods, since that is the obvious length of a production cycle, especially for crops. But since some production decisions affect several time periods, as will be elaborated upon in the following, the farm optimisation in the sector model is done for a three year period. The one year periods are defined to begin on September 1st, based on the assumption that the cash crops are harvested by then, meaning that planting decisions for the next period are made around that time. Some of the roughage crops are harvested after this date and consumed as feed in the next period, and all roughage crops can be stored and used in later periods.

Since there are a number of submodels, which are all producing data for each other, a note on endogenous and exogenous data is needed. It is not sufficient to use the ordinary terms endogenous and exogenous when trying to explain how data are transferred from one submodel to another.

Therefore we introduce the terms model-exogenous, submodel-exogenous and submodel-endogenous. Model-exogenous is defined as something determined outside of KRAM. Submodel-exogenous indicate a variable determined in the KRAM model but the variable is exogenous to the submodel in question. Finally submodel-endogenous is used to indicate that a variable is determined in the submodel in question. For example the crop yield is determined in the manure and fertilisation submodel. When discussing this submodel the crop yield is submodel-endogenous, but when discussing the sector model the crop yield is submodel-exogenous.

In the following chapters we move on to describe the different submodels in KRAM in more details.

2 The Feeding Submodel

The feeding submodel is a one-period non-linear optimisation model, which in a later version will estimate the optimal milk yield per milking cow as a profit maximisation problem based on expected prices of milk and feed units (FU) using a non-linear production function. Due to data problems and time limitations the feeding model is currently not used. Instead a fixed amount of feed is needed to produce a fixed amount of milk in the sector model. The rationale behind the feeding submodel is to be able to detect changes in the highly non-linear demand for feed as a reaction to changed prices or production methods. The submodel is also created because an extra non-linear yield function in the sector model might complicate the solving process. The sector model uses the optimal output from the feeding submodel and determines the optimal feeding plan based on constraints regarding what combinations of feed components are possible.

The feeding model may be extended later to include the feeding of slaughter pigs and sows. This is relevant to include, since the feeding influences on the nitrogen content of the manure. When this is applied the feeding model will also determine the amount of manure from the animals.

2.1 Inputs and outputs

Submodel-exogenous inputs in this submodel will be the total expected costs of roughage crop production, comprised of the expected direct costs plus the expected opportunity costs, which are determined in the price expectation submodel. The opportunity costs express the lost income from not growing a cash crop on the land used for roughage crops, and they are calculated as a function of last period's opportunity costs and the change in expected prices for this period. Furthermore, the milk yield function, which is model-exogenous, is used here. The output is the optimal energy use (in FE) and milk yield, which is forwarded to the sector model.

The current input and output from the feeding submodel is only the optimal milk yield and feed use, which is model exogenous.

3 Manure and Fertilisation Submodel

The manure and fertilisation submodel is a programming model with the per hectare revenue less nitrogen costs as the objective function. Non-linear yield functions in nitrogen (fertiliser equivalent nitrogen amounts for manure and dung) are used for most crops. 22 different crops plus a catch crop are considered in KRAM, covering about 98-99% of the arable land in Denmark. But since KRAM only simulates the effects for the full time farmers only 74% of the total arable land is included (SJFI, 1998). Manure and dung may be applied on the crops using three different application techniques: traditional spreading, trailing pipes, and direct injection into soil.

The model is explicitly considering fertiliser nitrogen and ten different kinds of manure and dung. The differences between the manure and dung types arise from different animal types. The utilisation rates for manure and dung varies with the application technique and the crop applied upon. Using a preliminary guess on the crop mix, a manure and dung clearing constraint is applied. By varying application technique or the amounts pr ha of manure and dung, but not the crop mix, all manure and dung must be used exactly. Fertiliser may be applied, if the economic optimum is not reached by using manure and dung.

This submodel is a one-period model, which is solved for each of the three periods relevant in the sector model. A separate manure and fertilisation submodel is formulated for each of the 84 farm types in KRAM, since they all have different crop mixes and in some cases even different yield functions, because of different soil types.

Currently, the crop yield is a function of the nitrogen application only, but it may be interesting to include other factors such as phosphorus or pesticides.

Since some of the assumptions used when solving the manure and fertilisation submodel may be changed in the sector model an iterative approach is utilized. In the first iteration the expected crop mix is last periods optimum. It should be noted, that the total cropped area may or may not be the same as last year, depending on investments in land determined in the structural development and investments submodel. The expected amounts of available manure and dung are also used in the first iteration, which are calculated using the optimal feeding scheme determined in the feeding submodel and an assumption that all the capacity (determined in the structural development and investments submodel) is used. In the following iterations a new guess of the crop mix and available manure – being the optimal levels from the same period in the sector model – re-enters the manure and fertilisation submodel. The iterations stop when the sector model and the manure and fertilisation submodel both uses all the dung and manure exactly.

3.1 Inputs and outputs

Submodel-exogenous inputs from the price expectation submodel are expected prices on inputs and outputs. The structural development and investment submodel provides the expected number of animals and the total area of the farm. Important technical parameters, which are explicitly considered in this submodel, are the combinations of the different manure application techniques with different costs and utilisation rates, and the yield functions. Finally the amounts of manure and dung available and the crop guess enters in the first iteration as (qualified) guesses, and in the later iterations as the solutions from the sector model.

For each crop a vector stating the optimal yield, optimal applied amounts of each of the 12 nitrogen sources and the total cost associated herewith enters into the sector model. The specific costs and achieved utilisation rates are placed in a text file in order to calculate further on this when the whole KRAM model has finished.

4 Farm Optimisation Submodel

The farm optimisation submodel is a Positive Mathematical Programming (PMP) model, which optimises the gross returns on the farm by choosing the optimal animal and crop production. The PMP approach applied in KRAM is currently the version proposed by Paris and Howitt (1998). An interesting development of the original PMP method, which has been conducted by Heckelei & Britz (1999) is currently evaluated, and might be applied. In their proposal maximum entropy (ME) recovery techniques are used to estimate the regionalised PMP cost functions such that they ensure exact calibration to the observed regional crop mix, and describe the full PMP cost matrix. This discussion is further described in (Wiborg et al., 1999).

The farm firm models in KRAM are recursive three-period models, meaning that in the beginning of period t the optimal production on the farm in period t, t+1 and t+2 is decided based on the expected prices for each of the three periods. In period t+1 a new optimal production for period t+1, t+2 and t+3 is found, and so on. This means that only the first period in the three-period solution derived from solving the three-period farm firm model will remain fixed, while the next two periods are subject to changes later. This corresponds to the farmer's optimisation problem: in the beginning of period t he will plan which crops to grow in period t, t+1 and t+2, but in the beginning of period t+1 he may change the plan made last year. However, the decisions made in the beginning of period t have some implications on later periods. For example, most roughage crops used in period t are grown in period t-1. Therefore, the roughage feed used in period t+1 was grown in period t, and thus the feeding plan in period t+1 has to be selected according to the available feed when solving KRAM for the next period, where period t+1 is now the first of the three periods.

Comment: Jeg kan ikke se hvor du vil hen med det

Several reasons motivate this approach, which admittedly is more complex that a one-period model; the major being the wish to simulate the farmers' decisions as closely as possible. One example where the three-period approach has clear advantages to a one-period approach is in the determination of the crop mix, since the crop mix in period t is restricted by the choice of crops in period t-1. It is impossible to grow grass seeds unless an equivalent area was grown last year with grass seeds laid down in barley or mature grass seeds that can be used another year. It is furthermore impossible to plant winter crops if late harvested crops such as beets or maize were grown on that area in last period. In a one-period model similar restrictions could be introduced, either by demanding the crop mix must be repeatable, or in a recursive manner by restrictions based in last period's crop mix. However, in a one-period model it would be difficult to incorporate a motivation for farmers to grow crops for the purpose of extra profits in subsequent periods, and especially so if price changes are expected to occur later (see below).

Investments are another example. An investment is by definition (in KRAM) decided upon between periods, or actually in the end of one period. KRAM does not allow the investment to take effect immediately, but rather one full year after the investment decision was made. Take the example of an investment in a new cowshed. Using the period labels from above, in (the end of) period t-1 the decision is made, during period t the building is constructed, and at the same time the farmer increases his stock of breeding heifers. At the beginning of period t+1 the new building is ready, and at the same time his milking cow herd can be increased, since heifers in the correct age and amount are ready[2]. These decisions, which clearly have medium term planning horizons, are made clear and visible in a three-period model set-up.

A final example is simulations of farmers' reactions to politically induced changes that are planned several years ahead. For example the Agenda 2000, which was agreed upon in 1998, defines some changes in the Common Agricultural Policy of the EU (CAP) until 2006. If the farmer has knowledge of this kind of changes it is sensible to allow changes in the farm production structure in response to the CAP changes. The alternative would be equivalent to the assumption that the farmer is constantly taken by surprise by new policies, even when they have been common knowledge for a number of years. An interesting effect of this approach is that KRAM yields different results to otherwise identical scenarios, if one scenario assumes farmers have pre-knowledge of the policy change, while the other assumes the change is unexpected.

When solving the sector model a convergence criterion is applied to check whether the chosen crop mix uses all manure and dung. If so, the model will continue to the market model, if not, a new iteration will be initiated, starting with the manure and fertilisation submodel. This time the manure and fertilisation submodels will use the optimal crop mixes from the sector model as guess.

4.1 Inputs and outputs

From the structural development and investment submodel the capacity (stable and acreage) and from the price expectation submodel the expected prices on inputs and outputs enter this submodel. Furthermore a number of technical parameters such as crop rotation restrictions are incorporated. From the feeding model an optimal energy use and milk yield enters this submodel, and from the manure and fertilisation model we get the preliminary manure and fertilisation allocation and yield per ha for each crop.

[2] To clarify, in Figure 1 the feeding submodel, the manure and fertilisation submodel and the sector model is solved "in the beginning of" period t, while the other submodels are solved in "the end of" period t or "between" period t and t+1.

The outputs from this submodel are the ready-to-solve farm firm optimisation problems, which will be utilised in the sector model. The individual farm firm models are not solved here but enters unsolved into the sector model all at one time.

5 Sector Model

The 84 different farm firm optimisation models are all solved simultaneously, together with various equilibrium conditions in the sector model. The optimisation criterion is the sum of the gross margins in the sector. In KRAM it is calculated as the gross margin from each farm firm group weighted with the number of farms in that group. Also when applying the market clearing constraints, each representative farm firm model is multiplied by the number of farms in that group. An example is, that the farm type 1 sells 100 piglets, and there are 100 farms of farm type 1 present, giving a total of 10,000 piglets sold. If farm type 2 is then buying 200 piglets and represent 50 farms, the market will clear. These constraints, which are formulated for trade in manure, in piglets in fattening calves and in straw are tying the different farm optimisation models together.

As discussed in the farm firm model, the solutions to the optimisation problems are compared to the premises used in the manure and fertilisation submodel and in case of discrepancy a new iteration is initiated. Otherwise the optimal animal and crop production are forwarded to the market model.

5.1 Inputs and outputs

Inputs to this model are the (not solved) farm firm models, and the information used in the equilibrium constraints include the number of farms of each farm type (from the structural development and investments submodel), as well as submodel-exogenously defined net exports of piglets and fattening calves. In later versions of KRAM the net export might be estimated in the market submodel using for example the Danish – German price ratios for these goods.

If convergence is achieved the production is forwarded to the market model.

6 Market Submodel

The purpose of the market submodel is to determine the obtained price of the production found in the sector model, where expected prices were used to determine the production. This submodel is the first model solved "between" period t and t+1. This and the following submodels serve the purpose of determining changes occurring before the next period, where the feeding, fertilisation and farm production will be solved again for the new period.

The market submodel uses the total production of agricultural goods derived in the sector model together with a model-exogenous sales curve to calculate the market clearing prices. Using the small country assumption ratifies the use of fixed prices/year in the first versions of KRAM. These values are calculated using FAPRI world market price predictions (FAPRI, 1999), CAP policies, relevant domestic conditions and, naturally, the scenario in question. The aim is to use more elastic sales curves in later versions of KRAM, especially if special products such as organic products are included. This is necessary since these products are mainly traded on a national market, where prices can not be assumed to be independent of production. Currently the mistake by using fixed prices is expected to be small, since the Danish production comprise a small part of the world market quantity, and most products are assumed to be sold on near perfect markets.

The market model multiplies the equilibrium price vector with the netput vectors produced in the sector model, thereby calculating the farm group gross margins. These gross margins are eventually forwarded to the price expectation- and structural development and investment submodels, while the equilibrium price vector is forwarded to the price expectation submodel.

The price of labour is calculated using model-exogenous information on unemployment and the development in the general economy in the region. This implies that the change in labour costs is not homogeneous across regions, since some regions may show good off-farm employment opportunities, while other regions do not. This model-exogenous information has been achieved from Filges et al. (1998).

7 Price Expectation Submodel

In the previous submodel the realised prices in period t were found based on achieved production. The price expectation submodel then determines the expected prices for the periods t+1, t+2 and t+3. The reason for using expected prices in the optimisation models is, that farmers are price takers, and have to make both planting and investment decisions more than a year before selling the goods. The farmer's information set when selecting the farm production does therefore not include the equilibrium prices, but rather his expectation of them. A number of other programming models have used endogenous prices (Horner et al., 1992; Jonasson and Apland, 1997). This may be reasonable in a long-term equilibrium, where all producers and consumers have correct price expectations; but since KRAM is a non-equilibrium model working its way though the years this assumption would not be satisfying here.

Therefore, fixed expected prices are used in the farm optimisation model where the production decisions are made and the achieved market clearing prices are determined later, in the market submodel.

For most goods an adaptive price expectations model (Nerlove, 1958) is used to estimate next period's expected prices. The idea behind the adaptive expectations hypothesis is, that the price expectation for a given period and good is a function of the price expectation in the last period and the realised price in that period. To this classical adaptive price expectation model we add a policy induced expected price change in period t.

The adaptation is only in effect for period t, where the realised prices in period t-1 are known. For period t+1 and t+2 the expected prices are determined as the expectation for period t plus the expected policy impact. It should be noted, that the expectations for period t+1 and t+2 will be reestimated when the model runs the following years.

A few goods, such as labour, have other price expectation mechanisms. The price of labour is simply expected to increase at a constant rate, i.e. the expected labour price in region X is the equilibrium price increased by a fixed percentage. This approach has been chosen since these prices tend to be sticky, and are more determined by collective bargaining than by labour supply and demand in the sector.

7.1 Inputs and outputs

The only inputs to the price expectations submodel are the expected prices determined in the previous period, the equilibrium prices estimated in the market model, and the model-exogenous policy expectations. The policy expectations may or may not change in a scenario, depending on whether it is assumed the farmers have early knowledge of policies.

The output from the price expectation submodel is the expected prices for all relevant goods and services for the next three periods. This information is used in all other submodels, except the technology submodel.

8 Structural Development and Investment Submodel

The purpose of this submodel is to estimate two things: First, the structural development as a function of the development up till now and the economic performance in a scenario, and secondly, the investments in land, milk quota, and stable capacity for sows, slaughter pigs and dairy cows. Investments in other assets, such as production capacity for poultry and the other cattle types are either model-exogenous or calculated as a function of the animal types considered here. The structural development and investment submodel is still not constructed in its final version, and the present chapter represents the current expectations to the submodel. Until a study in Danish farmers' investment decisions has finished we are using a temporary version of this submodel. This version does not utilise the information from the sector model to estimate investments, and therefore the final version is expected to clearly outperform this version.

The structural development and investment submodel is an econometric model, using a number of relations estimated on panel data set describing Danish farmers structural development and investments. These panel data are accounting data from the SJFI database (SJFI, 1998).

The investments in a certain farm group are expected to be a function of last period's profit, last period's profit in competing farm types, the farm group, and possibly other factors. For example it would be relevant to include new legislation or policy expectations into the investment decision, but this is impossible to do in a general way. Therefore such factors must influence the decisions through the scenario assumptions. Further information about the investment decisions in the KRAM framework will follow in a separate paper.

The output from this submodel is the number of farms in each group, the stable capacity for milking cows, sows, slaughter pigs and the land available on all farm types.

Comment: Hvorfor - eller på hvad?

Comment: Specificer

9 Technology submodel

The purpose of the technology submodel is to adjust the technical coefficients in the model in accordance with the expectations to technological progress. Since the structural development has already been established, changes in the overall productivity due to inefficient farms being absorbed by efficient ones should not be included here. The figures needed are the on-farm technology development only, and these changed coefficients are used in the feeding-, manure and fertilisation- and farm optimisation submodels. An example of a parameter changed in the technology submodel is the labour use in each process. If it took 16 hours to grow a ha. wheat in period t, it might take 15.8 in period t+1.

Comment: Jeg køber den ikke umiddelbart. Jeg tror at hele ideen er, at tekniske ændringer ikke er noget der kan modelleres - sker typisk i spring. Så her har vi netop plads til, at man kan gå ind og 'håndstyre' det ... og at det er synligt hvad man gør.

Over time we hope to establish a link between the technology submodel and the investments, such that the technical coefficients are changed according to the level of investments. Currently this link is not established.

10 Concluding remarks

The KRAM model framework is novel in combining this kind of detail in the optimisation processes for feeding, manure application and crop mix for a sector model. It produces the path taken to the long term equilibrium, as opposed to the equilibrium in itself. Since KRAM is working on a quite disaggregated level and produces the amounts of nutrients applied, yields taken away etc. the model provides a good basis for estimating environmental impacts of a given scenario.

When trying to analyse the impacts of agri-environmental policies KRAM has the drawback of omitting part time- and hobby farms. But on the other hand this omission means, that the modelling of the farmer's reaction is more precise, since profit maximisation can be assumed, and since the data available for full time farmers are more accurate.

The major drawback of KRAM is that the level of details demands a huge amount of data to just calibrate and initiate the model. When working with such a large number of variables a number of them will undoubtedly give unrealistic results. This problem is a well-known problem in programming models, where clear confidence intervals on the results are impossible to provide. As in other programming models, the answer to this problem is to compare a scenario to a reference scenario or another scenario, and not to the real world situation.

Our hope is that the level of detail that constitutes this problem, in some ways also helps in counterbalancing it. The design of KRAM, as composed of several more or less independent sub-models, makes it possible to track the individual variables in their way through the model. The explicit inclusion of the many variables will make it clear which assumptions are made, why they are made, and in which way they influence the results. Therefore, after the run of each submodel, the (partial) results from that submodel should be subject to a careful scrutiny, and in case of discrepancies with available knowledge and common sense, the assumptions that bring about the results should be revised accordingly. This revision is made relatively easy with the design of KRAM, where individual submodels can be revised and run, independent of the full model.

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