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DATA HANDLING RESTRICTIONS ON LARGE SCALE AGRICULTURAL MODELS†

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In a large-scale agricultural model a sizeable amount of low level data undergoes several stages of processing. In designing a model, uncertainty and complexity will restrict the generality of computer-implemented stages and much of the processing will be manual. The resulting model is likely to be inflexible to changes or else require as long again to modify and rerun as to design another model in order to evaluate another policy. By recognizing the necessary constraints imposed by mass data handling, the proportion of time spent on data problems could be reduced. Emphasis should be placed on defining beforehand as explicity as possible an acceptable methodology and what the specific uses of the model will be.

1 INTRODUCTION

The past twenty years has seen the development of several large-scale mathematical programming models of national or regional agricultures. Referring to the USDA representative-farm model of U.S. agriculture, Sharples noted that "no model in the history of production economics has received as much widespread research support in the form of research funds and professional manpower" [7, p. 353]. Typical of these models is the broadly stated goal of "a systematic framework that would provide timely, short-run estimates of production, resource use, income, and related variables under alternative government farm programmes" Sharples and Schaller [6, p. 1523].

To date, no model has achieved this objective satisfactorily but it is admitted now with perhaps more candour than before that these models, especially when dynamic, recursive, or time-oriented, "pose massive and perhaps prohibitive data problems if the number of regions is large" Hall and Heady [2, p. 268]. However, a striking feature of the literature and reports on the projects that have been attempted is that very scant documentation is provided on the acquisition, collation and handling of

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data. This criticism, along with many other relevant ones, is enlarged upon by van Dyne and Abramsky [10] and also pointed out by Thomson [8]. The possibility that inherent problems of mass data manipulation lie at the roots of the apparent lack of success of large-scale models has not yet been sufficiently investigated.

The relative neglect of data problems is probably a consequence of modellers' primary interest being economic analysis. The agricultural economist is interested in the methodological and economic consistency of his models, and even though he spends most of his time in large-scale modelling exercises dealing with data problems, he does not exhaustively report on them. As noted by Watt [13], trends in the modelling of complex biological and economic systems seem to indicate a necessarily increasing preoccupation with data processing and statistical analysis.

The ideas expressed below relate to the feasilibity of constructing useful large-scale policy-evaluation models. Controversial methodological problems, the origin of which would seem to be the simultaneous achievement of the antagonistic goals of realism, precision, generality and resolution, are not considered (see van Dyne and Abramsky, [10]). This paper concentrates instead on the premise that the chief restriction in the development of the envisaged quick turn around national policy evaluators has been that of data handling and processing. By studying the necessary structural relationships between various parts of the model and the difficulties of initially defining them, it is shown that there are intrinsic physical constraints on the meaningful handling of the vast amounts of data that are required to describe the behaviour of a few chosen indicators.

On commencing a modelling exercise, one has a choice between two broad approaches. On the one hand, one can try to design a general and necessarily very complex model which will run several pre-determined evaluations. The difficulties of conceptualizing all the operations that will need to be carried out will severely restrict the size and generality of such an attempt. Alternatively, one can aim at constructing a simpler model to simulate the results of a specifically defined policy. It is argued below that too much emphasis on the first approach results not only in a structurally inflexible model, but frequently in insurmountable problems in terms of the resources and time needed to build the structure. Choosing the latter approach, however, gives rise to a restrictive model in that it can only provide solutions to a very limited range of problems.

Further crucial questions arise when considering possible uses of either type of model after the originally envisaged runs have been completed. The more general type of model would be very difficult to modify structurally or re-adapt, while the simpler model, lacking generalized data processing routines, would require an equal amount of time to carry out another policy evaluation.

The paper is organized in the following manner. A large-scale agricultural model is defined in Section 2, and is then conceptualized as a sequence of processing blocks in Section 3. In the next section the properties of each such block are analysed and the relative merits of implementing one of these by computer or by hand are examined. The difficulties of designing an entire model and thereafter altering it are discussed in Section 5. The feasibility of maintaining a current input data bank for a constructed model, together with other implications, are next considered.

2 DEFINITION OF A LARGE SCALE AGRICULTURAL MODEL

The main criterion for distinguishing a large-scale model is regarded as being the extent and disaggregated nature of its data base. Such an agricultural model must be based on data originating at the farm level over a significantly large section of a country. Large-scale aggregative programming models and national gross margin analyses would fit this description whereas econometric or elasticity-based models would not. The latter, for example Ray and Moriak [5], mainly use data derived from measuring certain higher level indicators of the agricultural sector and therefore need to manipulate a smaller volume of data, although problems similar to those discussed below may still restrict data availability.

The data base necessary for the construction of a large-scale agricultural model is usually compiled by governmental institutions and appears in published tables. It must be noted here that the pre-processing required even before these tables appear usually results in a delay ranging between six months and three years. This has obvious implications for trying to run a model using current data.

A large-scale model therefore can be viewed essentially as one which uses vast amounts of data and explains their interrelationships in order to provide insight about a few chosen key indicators. So one starts with a large quantity of relatively crude data, processes it, and ends up with a small quantity of data of high information content.

Although this paper concentrates on the inherent limitations that exist when developing a large-scale agricultural model, many of the points mentioned are shared to some extent by all models which manipulate data.

3 A MODEL AS A SEQUENCE OF PROCESSING BLOCKS

With such a large data base it is necessary to go through several stages of data processing. As Thomson [8], and van Dyne and Abramsky [10] have pointed out, one needs to compartmentalize the running of the model in order to make it manageable. If we call each unit of activity which executes a particular stage of modelling a processing block, we can draw up a sequence of these that must be traversed at least once in running a model. It is hard to imagine a large model using fewer than six such blocks.

The distinction between successive blocks need not be precise and two processing stages may be executed as one block. The processing blocks need not be in strict sequence and feedback loops which respecify certain data items may exist. However, these complications do not change the basic arguments since the same quantity and type of processing is still required. If anything, the feedback loops add greatly to inflexibility problems discussed later since they are more stringent with respect to their inputs. There is the added possibility of additional raw data being required as an input at stages further along the modelling processes but these by definition constitute only a small portion of the data base.

Figure 1 is an example of the data processing blocks required for a large-scale agricultural linear programming model such as APMAA [12] or CARD [11]. A modelling team usually enters the process at the end of stage 2. Stage 3 may be trivial in some instances but in others where the data are not standardized or must be obtained from obscure sources it may be a major hinderance. If certain key elements are missing at this point, they may need to be recompiled at stage 2. Stage 8 may also seem trivial but has been mentioned most frequently as a major practical constraint on obtaining meaningful results [7]. But wherever one enters the process, it is still not a certainty, as evidenced by the numerous as yet uncompleted models, that one will ever emerge from it.

4 DATA PROCESSING BLOCKS

4.1 GENERAL DESCRIPTION OF DATA PROCESSING BLOCK

Basically a data processing block is a unit that operates on a certain defined data set, adds to its information content, and then passes on a new set of data. It is important to note that the input data must be clearly defined because it is useless trying to design a process that will operate on "approximately this data". The output data as an end in itself is not so rigidly restricted except where it is an input into the next block. The added information content emerges either through the relationships among several variables being reduced to fewer higher order variables (as in the solution of a linear program), or else in their structural re-arrangement (as in building a matrix from many diverse numbers).

In order to keep the compartmentalized structure manageable it is usually more convenient to record or store the information at the interface of two blocks. Examples of storage devices that can be used are paper, computer cards, magnetic tape, or computer discs. In many cases it is worthwhile storing this data for future possible uses, especially if it is relatively unambiguously defined and recording its mode of storage is not too difficult. For example rainfall data is much easier to store and adapt for future usage than are linear programming matrices with their various assumptions, standardizations and simplifications. Relationships between blocks may in some cases make this storage unnecessary but the amount of processing will not significantly decrease.

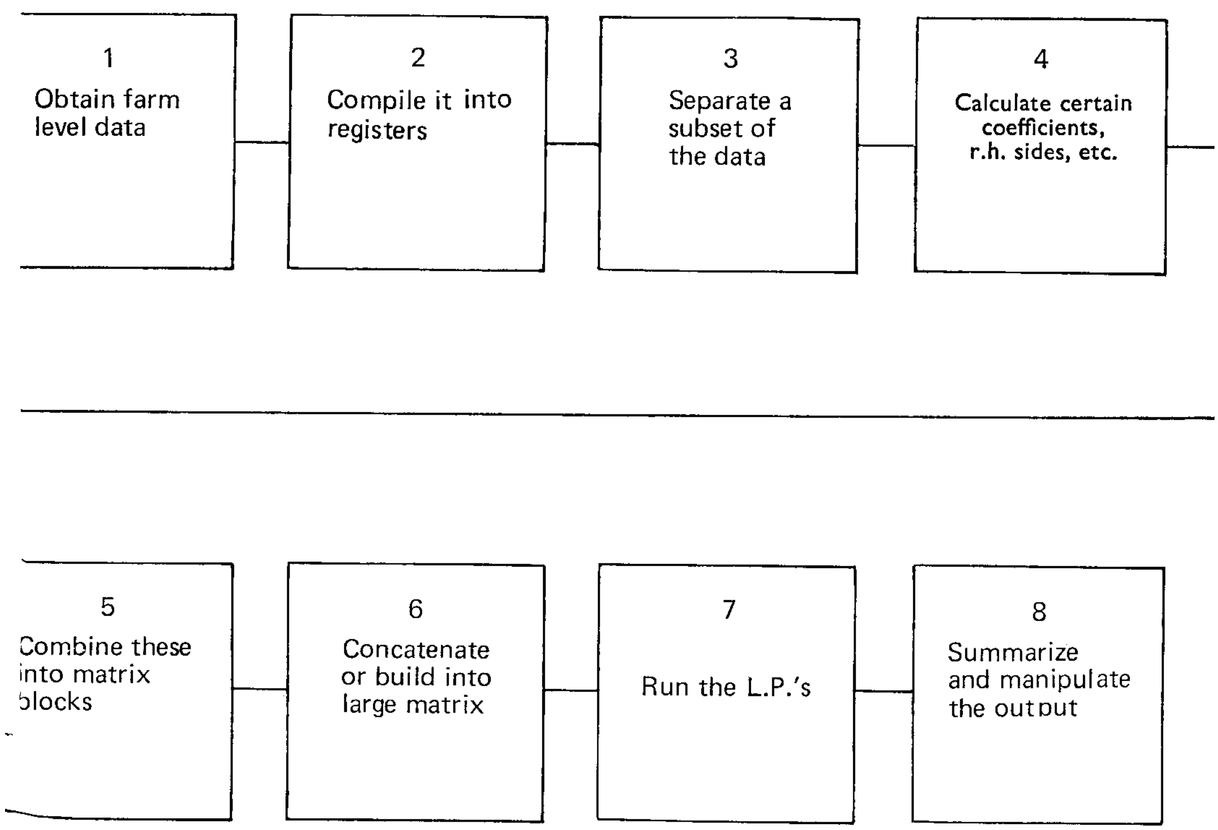

FIGURE 1. *Sequence of Processing Blocks for a Large-Scale Agricultural Programming Model.*

The necessary processing may be accomplished either entirely by computer, entirely by hand, or by a combination of both. In the example given above in Figure 1, block 1 is usually carried out by hand whereas block 7 is always solved by machine. However, in most of the blocks there is a choice to be made. The implicit differences and constraints of the two means of approach are discussed next.

4.2 COMPUTER IMPLEMENTED DATA PROCESSING BLOCKS

Computer programs are best at doing things which require many repetitions of the same operations. They are therefore most suitable for use when large amounts of data are to be operated upon or else where an identical process will need to be repeated at some future date.

It is essential that the exact process to be carried out in a program be clearly defined before the programmer starts trying to implement it. This is a difficult task, and in an uncertain complex system is frequently almost impossible. It has been estimated that more than 90% of system analysts' time is spent trying to elicit from the customer exactly what he wants done [4]. Not only must the analyst conceptualize all the steps that his program will need to carry out, but he must also be sure of the exact form of the input data and output from the program. Especially difficult with respect to computer processing of data is the task of accounting for the possibility of missing or inconsistent values, something that can be resolved on the spot when processing by hand.

The greater the number of pre-envisaged functions or different policy evaluations the program needs to fulfil, the more are the above difficulties compounded. In one's ardour to create a general program and account for all eventualities, not only do the complexity and size of the program rise dramatically, but one is frequently left with a system where a high proportion of its designed capacity will never be used. However, even more crucial is the fact that such a complex program is generally very much more difficult to change or adapt to respecifications—and trying to do so rapidly leads to an overly cumbersome program with unacceptable inefficiency.

In a field where the methodology is not yet clearly defined, one will find while designing a processing block that the current model specification is either not feasible or else can be improved. A feedback learning process causes the block to be respecified, updated and re-evaluated. One result of such manipulations is that the completion of a generalized computer-implemented processing block is expected to be time consuming with an associated high variance, especially if strict discipline on deadlines is not enforced.

Writing such a program is a form of capital building which requires a considerable amount of highly skilled man-hours. The decision on whether such an investment is worthwhile should depend mainly on how many runs are envisaged and how long the system is expected to survive. Unfortunately, these criteria may not be subject to evaluation prior to the completion of the initial runs. Consequently research-oriented models are often relegated to hand processing.

4.3 DATA PROCESSING BLOCKS IMPLEMENTED BY HAND

Most of the attributes of this method of approach are the converse of those mentioned in the discussion above on computer implemented blocks. Processing by hand can start sooner, requires relatively unskilled personnel, is tedious, and very time consuming. The main shortcoming is that it is just as time consuming to repeat the same calculations on different data. Another disadvantage is that it is also more prone to errors which are difficult to detect. The main advantage of manual processing is that there is a relatively low variance associated with the time of completion since one can judge how much work is necessary after a simple experimental trial on a small subset of the data.

4.4 COMPARISON BETWEEN THE TWO TYPES OF PROCESSING BLOCKS

The main differences between computer and hand implemented processing blocks are listed in Table 1. Since certain operations are naturally more amenable to computer or manual solution, a block will frequently comprise a combination of the two, producing a mixture of their relative merits.

TABLE 1. *Summary of Relative Attributes of Computer or Manual Processing Blocks*

	Computer implemented	Hand implemented
1. Time between initiating project and beginning construction of model ..	long	short
2. Execution time of process once model implemented	fast	slow
3. Variance of time until answers available	large	relatively small
4. Possibility of changes in structure or function	inflexible	flexible
5. Possibility of changes in input and output data	inflexible	flexible
6. Overcoming unexpected difficulties..	very difficult	usually easy
7. Repetition of process	easy	just as time consuming
8. Personnel necessary	highly skilled	mainly low skill
9. Accuracy	high	lower
10. System transportability	relatively unadaptible	easily transferred
11. Intellectual rewards	stimulating	monotonous

5 PROBLEMS ASSOCIATED WITH BUILDING MODELS

5.1 PROBLEMS OF INITIALLY DESIGNING A LARGE-SCALE MODEL

Having considered the difficulties and constraints inherent in designing a single processing block, we now discuss those additional ones that arise when trying to design a model comprising a number of such interrelated blocks. Van Dyne and Abramsky have pointed out that "considerable evidence suggests that the potential use of the model is not clearly specified before the model is designed" [10, p. 59]. Nevertheless it is clearly necessary to "set the rules" before starting data gathering and model building. In an operation where the methodology is still not firmly established, and where enormous amounts of data will be handled, it is inconceivable that a modeller can envisage all of the problems he will encounter and devise beforehand the methods he will use to overcome them. At best he can rely on a summary of previous experience and he must to a certain extent venture into the unknown, hoping to be able to overcome problems as they arise.

It seems reasonable to expect that before commencing a model-building exercise which is going to use relatively large amounts of resources, at least the number and sequence of processing blocks required should be established. A choice then exists as to whether each of these will be implemented by hand, by a generalized computer program, or a combination of both.

If a generalized computer implementation is envisaged then the difficulties discussed above with respect to isolated processing blocks still apply, but to an even greater degree because of the strict interrelationships between consecutive blocks. Now one must preconceive not only the inputs, outputs and structure of one block, but all of these at the same time, a massive task.

Some examples of the sorts of parameters one has to decide upon can be listed. What are the possible inputs and outputs of each block? Can one obtain the relevant data or can it be made available? Will there be sufficient personnel and computer resources, including machine time and capacity, to perform the task? In what units will all the defined variables be expressed? What are the maximum dimensions and quantities of data that will need to be handled? (A simple example of such a difficulty is that of deciding on a FORTRAN printout format for figures such as land constraints which may range from 50 to 10^5 hectares. Any choice is either wasteful or inadequate.)

Even problems such as deciding on a standardized list of names and codes beforehand is an enormous task since it implies that the modeller must decide at the outset as to what activity options he wishes to restrict himself.

In a large model the problems are compounded by the fact that the blocks are highly dependent on one another for data. If one reaches an insurmountable problem in one block, it may influence all the preconceived assumptions about the function of future blocks to be traversed. A similar situation arises when an unexpected change must be made to a block. The effects of the alteration will influence the design of all the others.

Thus in order to keep it manageable, too ambitious a general model cannot be planned, and, mainly owing to the high uncertainty associated with the completion date of each computer implemented block, many of the processing blocks in such an exercise will be manual. On choosing to assign a large portion of the data processing to hand, one must necessarily restrict the possible diversity of runs and only very few different policies can initially be planned for.

Therefore, whether the initial model is chiefly manually or computer implemented, it can be originally designed only for a few specific runs.

5.2 RESPECIFYING THE ORIGINAL MODEL

While the specified model is being developed new ideas, changes and proposed uses will appear. Continually giving way to these before completing the pre-defined exercise will greatly extend the initial completion date. It is usually true that these respecifications will be concerned with increasing the degree of resolution of the model. Bearing in mind the dangers associated with changes to the initial plan, one possible strategy which may be adopted is that these additions should be merely noted and then neglected until the initial model is completed. The question then arises as to whether one can implement these changes and improvements once the prototype model is operational. This is the topic of the next section.

5.3 FLEXIBILITY OF THE CONSTRUCTED MODEL TO CHANGES

Once a model composed of data processing blocks as described above has been built and the goals initially specified have been achieved, further possible uses of such a model must be considered. It is almost certain that one will want to test something not initially envisaged, or that one would like to improve certain sections by changing the functions of one or more processing blocks. To what extent is this possible in practice?

Of necessity we shall have to change the processing structure of at least one of the blocks. If we are fortunate, its input and output interfaces will remain unchanged and it will merely use a different technique on the same data to produce analogous output data in the same format as before. However, in practice this is most unlikely. The next best situation is one where only a relatively small amount of data needs to be added to one block. Once again there is a trade-off. If the block is far to the right of Figure 1, extra preprocessing blocks will be required to raise the extra farm data to the level of the block where the addition is made. If it is to the left, the amount of new data necessary, even though small in comparison to the overall data base, is likely to be considerable.

The most probable situation is that at least one of the data interfaces requires alteration, and this has implications for the adjacent block as well since it too then needs to be modified. If the block is computer implemented, changing it will most likely be cumbersome and inefficient in terms of computer space and time, and any subsequent changes may be almost impossible. If the block is manually implemented then much time needs to be spent re-processing by hand all the computations to the right of the point of change.

Jeffers [3] notes that it is frequently more difficult to document the assumptions, definitions and storage format of data than to list the data itself. Similarly, in a process such as the one above, it is essential that all changes be precisely documented, especially since more than a single person is usually involved in working on the model. However even more than is the case with data, describing the changes to a system and updating the operating manuals are very tedious tasks and frequently bypassed.

Experience and the evidence of the literature indicates that changes in a model are usually crucially dependent on the acquired skills of a single member of a project team and are rarely documented in sufficient detail. Should this person leave the project much time is likely to be wasted trying to rebuild this acquired knowledge, frequently indispensible in continuing the model. This dependence on individuals extends also to their acquired skills and experience in processing data manually, a function very difficult to document.

Thus one must take account of the problems of inflexibility discussed above and realize that a large-scale model probably cannot survive more than a few of these alterations before it becomes unmanageable due to problems of cumbersome programming, limitations of computer space, and the difficulties of documenting the updated model.

6 IMPLICATIONS AND GUIDELINES

6.1 FURTHER COMMENTS AND IMPLICATIONS

Many authors have expressed the advantages of building data banks for large-scale models. These, they imply, would be maintained current so that an established model could be run with more up to date statistics and allow the results to be regularly re-evaluated. However, there are several obstacles in the path of such developments.

First, maintaining a data bank must imply a definition of exactly what data might be necessary for a model. This implies, for the reasons discussed above, that the model needs to be strictly defined beforehand. This, in turn, means that the methodology has to have been established and accepted by the prospective users. This is certainly not yet the usual case for large-scale agricultural models.

Second, if such a data bank were computer based it would necessarily be very inflexible and restrictive when new questions were asked. If it were mainly manual, it would be very difficult to document the processes and skills required for this tedious task, and once accomplished, it would be just as inflexible for freshly posed problems. To these difficulties must be added the fact that some time elapses before data in even its rawest form becomes available, and models are perhaps doomed to always running on data several years out of date, precluding relevant short-run semi-predictive runs.

A serious methodological problem with large-scale models, especially when investigating long term dynamics, is how to include technological change. The data handling problems discussed above make solution of this problem seem even more distant, since such change usually implies alterations to the structure or totally new parameters being included in a model. The inflexibility of a constructed model would almost certainly be a strong deterrent to any attempts to implement such changes.

Funding for a model-building project may come from a number of sources, usually governmental. However, if they are from a private body they will most probably be for a model with a specific goal. Being subject to fairly stringent deadlines, much of the processing will usually be done manually. Once the project has given an answer to the specific question being considered the model is likely to be almost as intractable for use in answering other questions as it was at the outset, while getting commitments from individual researchers to stay with the team for further stages of the project will be hard since further development entails more monotonous manual number-crunching.

6.2 SOME GUIDELINES

Large-scale agricultural models would be of greatest use to policy makers if their results and predictions could be regularly up-dated, and this is one of the chief advantages of utilizing data banks. Thus once a researcher has decided on a model structure and data set, if he has sufficient confidence in its usefulness he should consider the use of a data bank. However the crucial prerequisite for this development is that the methodology of constructing and running a model has been firmly established and accepted by its prospective users. One cannot build useful data banks until the model's structure has been finalized, and as yet few large-scale models are claimed to be other than developmental. It appears that model builders should currently be most concerned with developing a methodology that will be accepted by policy makers. Once confidence exists in the processes being used, questions of building more general evaluators and data banks can proceed. Due to the extensive resources necessary for such operations, perhaps this exercise could only be attempted by a body which already maintains a substantial current data bank.

At the moment there is still much confusion as to what "building a model" involves. It is essential that as many of the goals and functions as possible be preconceived and planned before beginning a modelling exercise. Specific ends must be stated and defined to as great an extent as possible, even if this means waiting some time before beginning physical collection and manipulation of data. Once these questions have been decided, calculations should be made on a small subset of data to become familiar with as many as possible of the problems that will arise. These include data availability, missing values, infeasibilities, computer size and time limitations.

Having decided on the objectives and methodology to be employed in a large-scale computer model, economists should spend considerable time consulting with skilled computer analysts. One of the main gains from this exercise would be to force the modeller to define more exactly what he intends doing and on what scale.

Large-scale models being developed at present deal with quantities of data of a different order of magnitude to what most economists are familiar with. Many layment are indifferent between figures of billions of dollars because such sums are outside their normal sphere of experience. Being in a similar situation, large-scale agricultural modellers should try to grasp the differences in size between different orders of models and the amounts of data required. For example, APMAA [12] contains about 125 000 non-zero coefficients between stages 4 and 5 in Figure 1, each of which was calculated from lower level data by hand. Unless they make compromises between the size of the model and its realism, modellers will continue to find themselves frequently overwhelmed by the bulk of its data manipulation.

One can define a vertical run as one that traverses all the processing stages and a lateral run as one which uses preprocessed data at a certain point and working on the same base assumptions, calculates different insights regarding the system. Since high-level data is valuable capital, one should try to use it to its full potential and researchers working with large models should perhaps concentrate more on lateral analysis. Even the output of one run could in many cases be used to more advantage than it usually is. One could, for example, analyse the distributional effects of policies in more detail. Thus rather than building general programs to handle many types of data, one should concentrate more on constructing simple organized high-level data sets which could be used by simply written goal-specific programs for mainly lateral runs. The essence of such an exercise would be the reduction of all the data to a consistent, general, and clearly defined format.

Finally, it must be stressed that strict documentation of data acquisition and its handling must be enforced. This serves both as a reference for the future and also to provide a means of disciplining the precise recording of assumptions and latest progress.

7 CONCLUSIONS

This paper has argued that there are inherent limitations on the size and feasibility of a large-scale agricultural model. These are imposed by the implicit relationships within the data and its processing. One must clearly define the system that one is attempting to construct before starting. This model, whether implemented primarily by computer or by hand, cannot be expected to be useful for the evaluation of more than a very few policy questions. Once constructed, the model is either very inflexible to alteration or else takes as long again to evaluate a different policy.

Useful large-scale agricultural models would undoubtedly provide a significant new tool for economic policy analysis. The successful manipulation and interpretation of large quantities of data in engineering and finance is due primarily to a clearly defined methodology. The uncertain and very complex nature of agricultural analysis would appear to preclude similar immediate breakthroughs. Once the methodological inconsistencies have been solved, efficient handling of the large amounts of data involved seems to be a problem yet to be formally confronted. "For the time being we are performing work of several types of mass data elaboration rather than an optimum planning on a national scale" observes Eremias [1, p. 486] while Thomson describes the Newcastle-on-Tyne model as lying "somewhere between commercial data-programmes and the normal scientific research model" [9, p. 8]. A major question which arises out of the discussion in this paper is whether large-scale agricultural modelling belongs more to the field of systems analysis than to agricultural economics.

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