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EVALUATION REPORT - MSU LIVESTOCK SECTOR MODELS

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SCOPE OF REVIEW

The Korean livestock model completed under AID/Csd-2975 as reported in [4], is freely admitted by the MSU team to be trivial. It consists of accepting the "best judgement" of a committee, or model user, as to future prices and output, and merely using the computer to calculate the implication of these assumptions. All economic analysis is done outside the model by the committee or user.

The Korean livestock component of the recursive linear program [3], is also trivial.

A non-trivial livestock sector model, of the northern Columbian cattle industry [7], has been completed under AID/Csd-2975. This is the most complicated of the MSU livestock Sector Models, and has been used as the major basis for this evaluation. Two other MSU - type models have also been reviewed, they relate to Nigeria [6], and Venezuela [5]. Evaluations of these individual models are included as Appendix A.

The review of these models reported in Appendix A, leads to evaluative comments on Methodology, Economic Modelling and Usefulness in Policy Analysis. These major comments

lay the foundation for a review of the topics nominated by AID to ATAC in the "Attachment on Evaluative Services."

METHODOLOGY

Simulation can be defined as "Any representation of reality, which fails to reproduce reality exactly," and the MSU team tend towards this wide definition of simulation in their emphasis on general system simulation. They profess a catholic approach "using whatever technique is appropriate in modelling different portions of the system." This profession has been honoured in fact, to the extent that committee judgemental inputs, linear programming, distributed lags, and sequential differential equations have been incorporated within MSU models.

Nevertheless MSU livestock sector models have some generalised hall-marks which tend to distinguish them. These MSU hall-marks can be summarised as:

a) Computer implementation

b) Non-optimising

c) Sequential modelling of economic variables

d) Use of differential equations, approximated for computational purposes by the use of a discrete time increments

e) Use of distributed lags for the analysis of demographic problems

The MSU team can probably find counter examples to each of the above nominated methodological elements, but taken together these five characteristics would allow fairly accurate discrimination between MSU-type and non-MSU-type models.

Given the generality claimed by MSU, and the variety of modelling components actually used, there can be no question that an MSU model could be developed and modified to incorporate any desired characteristics - but the same can be said of a plain sheet of paper. Clearly the modelling deficiencies pointed to in Appendix A are not fundamental, they could be overcome. The question is whether they are likely to be overcome by the MSU team or their co-workers?

ECONOMIC MODELLING

The MSU team would probably consider economic modelling as one of their major strengths. I cannot agree. To me this is the area of greatest concern, and one which is very difficult to remedy. I am concerned on two counts:

1. Examples of fundamentally bad economic modelling occur in the livestock models.

   a) In the original Nigerian model, price formation was exogenous, unrelated to quantity supplied or demanded.

   b) In the Venezuelan model imports are treated

as a residual so that imports fall when domestic price rises. This in the face of an open frontier with Columbia over which cattle flow without restraint.

c) In the Columbian model the difference in quantity supplied and quantity demanded at time (t-dt) is used to calculate the change in price from time (t-dt) to time t. No attempt is made to explain how the difference in quantities supplied and demanded in period (t-dt) is resolved.

2. MSU reports focus on the simulation model, not the economic model. The available descriptions of the MSU models focus on the simulation model being used; and ignore the prior problem of the economic relationships that it is desired to simulate. Good modelling requires a clear destinction between what you would like to model, and what you are going to model. Differences may arise due to the cost of accurate simulation, or to unavailability of suitable software, or simple ignorance as to how the nominated economic features could be incorporated into a computer program. But it is important for users to be able to distinguish between what model builders would have liked to model, and what they have actually modelled.

I believe that the emphasis on sequential relationships which characterises MSU model building has unfortunate-

ly, influenced their economic model building. The MSU team repeatedly model allocation decisions sequentially, as for example: First land is allocated to food crops, the remaining acreage is then allocated to feed crops, and any remaining land is used for growing pasture, or: "As a general sales policy the model assumes the following priorities (for other than finished males): (1) old cows; (2) cows with reproductive problems; (3) growing males; ...." (7, close to figure II.6). The modelling seldom reflects simultaneous relationships, and many agricultural allocation problems <u>are</u> simultaneous.

There is also a tendency, as noted in 1 above, for the MSU team to either fail to close the endogenous system, or to close it with a residual which is likely to behave in an implausible fashion.

In any extension or renewal of contract no. AID/Csd-2975, increased emphasis should be placed on the economic modelling which should preceed, and be distinct from, implementation of a computer model.

Contract no. AID/Csd-2975 has a substantial training component. I believe this to be a vitally important function, but prime emphasis needs to be placed on economic modelling for sector analysis, not on construction or use of simulators. This latter is important as it serves to give empirical content to otherwise abstract economic models, but it is the quality of the underlying economic model

which determines the appropriateness of any associated simulation model.

USE BY DECISION MAKERS

The necessary and sufficient conditions for use of a model for use by decision makers are that they are exposed to the model and believe its results. The inherent merits of the model itself, and its internal consistency, are not determinants of likely usage. Decision makers do not have the time, nor frequently the expertise, to examine the internal consistency of the model. This they have to take on faith, or relate to a few common-sense measures as to whether the models output is plausible.

The Columbian model has little prospect of use by decision makers, since it was constructed as a training device, and not in response to a request by decision makers in Bogota.

Results from the Nigerian model have been sent to the Nigerian Government, but at this writing MSU do not know whether these results are being utilized in formulation of the 5-year plan. (Presumably not, since if it were being used there would likely have been follow-up requests for further analyses).

Policy recommendations have been made on the basis of the Korean model. It is [illegible] at this writing whether

they were accepted.

The Venezuelan model was developed in close cooperation with national decision makers, and was highly effective in influencing the Venezuelan Government to allow higher beef prices, and to provide a vigorous policy of credit and other assistance to livestock producers.

We have already seen that the treatment of imports as a residual led to inconsistent projections, where imports fall in response to increased domestic prices. It is probable, however, that the predicted beef shortage of the base run, and the prediction of increased domestic supply in response to the government policies were correct. Thus it would appear that even though the model was internally inconsistent, it was successful in precipitating a government policy decision in the direction which would have been taken on the basis of an internally consistent prediction.

It seems quite likely that the very simple and graphic visuals used by Miller and Halter in making their presentation had more to do with the impact of their policy advice, than did the complexities of the computer model used to produce the results.

There is a very important lesson here, on the importance of simple, clear and carefully prepared presentation of sector model results.

TRANSFERABILITY

As indicated above, the major limitation of the MSU approach lies in the economic modelling, rather than software and implementation. It is doubtful if we should hope for a high degree of transferability between countries, except as the same sort of economic modelling expertise is required in all cases. We should be able to develop people who are skilled in recognising the guts of policy problems, and able to abstract these into appropriate economic models. Clearly individual economists will develop their own style of modelling, so that the same features will tend to reappear in models contributed to by the same person. It is desirable, however, in principle, that each economy be modelled in its own right. Even where the technological possibilities are similar, it is possible that the behavioural characteristics of producers in the two economies may differ markedly. When canned software routines can be used to implement a model, this will be a distinct saving, but software should not dictate model structure.

FUTURE WORK

Four lines of future work suggest themselves:

a) A careful review of the economic logic used in the existing MSU models, and their future development to achieve

internal consistency, and to incorporate additional features needed to better represent the real problems and alternatives facing policy makers.

b) Some new modelling experiences in additional countries.

c) Training of personnel in economic modelling, and

d) Improved testing/validation procedures for economic models. If simulator gives a worse fit than simple linear extrapolation, should we use the extrapolation?

Consideration should perhaps be given to spreading this work amongst several institutions, since there is a need to foster debate and critical interaction, so that blantantly inconsistent modelling approaches can be identified and eliminated. Or, at the very least, to institutionalise some process of model criticizing. The criticisms made in Appendix A would have been much more helpful if made *ex ante*, rather than *ex poste*.

EPILOGUE

As indicated earlier, the Korean livestock model is trivial. This reflects a conscious decision by the MSU team that the scope for increased livestock production in Korea is slight, compared to the scope and need for increased crop production. It was felt, by the MSU team, that exploration of livestock development alternatives should

receive low priority.

By contrast the IRBD mission [2] put considerable emphasis on the expansion of beef production based on some 1 to 1.2 million hectares of semi-utilized native grasslands.

I cannot contribute, at this distance, to a resolution of whether MSU or IRBD was (is) right. I think it is reasonable, however, to advance the view that the disagreement stems largely from the background of the two experts involved. They both agree as to the existence of large acreages of "under utilised" native grassland. One expert was inclined to view this resource as capable of intensive live stock production a la New Zealand. The other expert was more impressed with the seasonal gaps in forage production, due to spring and fall droughts, and hence was inclined to view them more in terms of the hill country of Tennessee and Arkansas.

Three points are worth making:

a) This basic difference of opinion about the appropriate technology, did not emerge in either the IRBD or MSU reports. Each report proceeded on the basis of a unique perception of the value of the "under utilised" grasslands.

b) Resolution of the value of these grasslands cannot be achieved by the use of an economic model. The model, per se, is neutral as between the New Zealand and the Arkansas view of the hill country. No amount of "tuning" the model will reveal which view is correct.

c) If we know the production potential of these grasslands, an appropriate development strategy for them could be derived with very little reference to the rest of the agricultural sector. A partial analysis would be very revealing.

The moral is clear. Not only must our models be internally consistent, but they must also accurately reflect feasible technologies; and, if technological information can be pooled, and examined objectively, then useful development advice may be given without appeal to computer models.

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APPENDIX A

REVIEW OF INDIVIDUAL MODELS

Models to be Evaluated:

Four livestock models are available for evaluation under the rubric of the MSU "general simulation" approach. A thumbnail sketch of the status of these models would be:

a) Nigerian Model. This model was funded by Contract AID/Csd-1557. A well documented version is available in [6], but undocumented modifications have been made in it to produce [1]. As discussed below, the documented version is markedly deficient in its treatment of price, and market forces generally. Results from [1] have been submitted to the Nigerian Government, but the MSU team do not know if they have received serious attention.

b) Columbian Model. This model was funded under Contract 2975, with help from Rockerfeller. A well documented version is available in [7]. It is a substantial generalisation of the Nigerian model, with much more plausible price/market characteristics. Unfortunately, it was developed without direct involvement of official Columbian decision makers.

c) Venezuelan Model. This model was not developed by the MSU team, but by Al Halter, a former team member. A

superficial account of the model is available in [5]. It is a slight improvement on the Nigerian Model, but still with obvious internal logical inconsistencies. It has however, been very influential with Venezuelan decision makers, and the decisions taken probably correspond to the decisions which would have been taken, even if imports had been correctly handled in the model.

d) Korean Model. The Korean model has been financed predominantly by Korean Mission Contract 184, it consists of three parts. The first involves linear interpolation between exogenously determined outputs [4, p.148]. Prices appear to be determined by demand elasticities. The second involves six linear programming activities, [3]. The third is still in the conceptual stage, to quote: "The livestock area will receive much more attention in later sector models", [4, p.147].

Given the rudimentary nature of the Korean model, there is no point in attempting a rigorous critique. The remaining three models are essentially cattle models, rather than livestock models.

NIGERIAN CATTLE MODEL

The Nigerian Cattle Model [6], is the original model from which the Columbian, Venezuelan and Korean models

have been developed. It is also highly mechanistic, to the point where it is doubtful if it is of any use as a predictor of economic behavior. Consider the following assumptions:

1. Prices are Exogenous. Price is not a function of quantity produced, but is introduced purely exogenously as Equation (BF27):

"(BF27) $P_t = a + bt + \sin(6.2816t)$

where P_t = price per animal in time period t, and

a, b, c = constants.

> This equation makes possible the investigation of effects of secular and seasonal changes in animal price. The model does not currently generate beef prices as endogenous variables ....It is a straightforward matter to bring supply and demand relationships together to compute endogenous prices, if desired, in a more detailed study of the beef industry."

Thus, a rapid expansion (or contraction) of the beef industry will have no affect on price of beef. Here is an economic model sans economics.

Of course the model will produce "reasonable" prices, since the price series are set independently of production, consumption, imports, exports or world price. But, the model totally fails the test of "internal consistency" - price does not behave reasonably in the light of the other economic variables in the system.

2. Demand is Independent of Price: Demand expands

exponentially irregardless of price, as in Equation (BF49):

"(BF49) $d_t = ae^{bt}$

where d_t = demand consumption in animal equivalents in time t,

e = exponential "e",

a, b = constants.

This equation assumes that demand grows exponentially due to population and income effects." i.e. We can set the parameters in (BF27) to double beef price every year, and consumption (BF49) will be totally unaffected. Again an economic model <u>sans</u> economics.

3. <u>Export Price is Equal to Domestic Price</u>: As shown in (BF60) the cost of imported cattle is taken as depending on domestic price:

"(BF60) $f_t = aq_tp_t$

where f_t = foreign exchange

q_t = imports

p_t = domestic price (as determined in (BF27)),

and a = constant."

There is no explicit comment in the text on this assumption.

4. <u>Imports are as Residual</u>. As indicated in equation

(BF51), imports are calculated as a residual, without effect on domestic price, nor influenced by world price.

"(BF51) $q_t = d_t - s_t$

where d_t = consumption demand in time t,

s_t = domestic supply in time t, and

q_t = imports in time t.

Imports necessary to satisfy demand and computed as the residual between demand and supply."

5. Summary. Domestic price is determined exogenously, and only affects the supply of animals. It does not affect demand, and only indirectly affects imports.

VENEZUELAN CATTLE MODEL

The Venezuelan cattle model was not constructed by the MSU team, nor is it in any way the responsibility of the MSU team; but it is a direct extension of the Nigerian model. It seems to have been highly effective in influencing policy: "In August 1972, approximately a year from when model development was undertaken, the government announced an increase in the price of beef to producers and consumers and a reduction in the market margin"; [5, p.431]. Unfortunately, the economic realism of this model must be seriously questioned, on two counts.

The first is that the base run, continuation of present policies, projects a continual expansion of the modern herd, from about 700,000 in 1971 to 1,070,000 in 2001, and a decrease in traditional herds from about 2,500,000 in 1971 to 1,780,000 in 2001, even though modern herds are assumed to lose B1,359 p.a., while traditional herds make a profit of B7,282 p.a.. Unless there are very substantial credit or tax advantages associated with modern production, it is hard to believe that unprofitable farms would really increase in number at the expense of profitable farms.

A second, more serious, deficiency of the model is its treatment of imports as a residual, i.e. having determined domestic demand and supply, imports are calculated as

Imports = Domestic Demand - Domestic Supply.

The consequence of this assumption is shown below, [5, Table 2]:

	Alternative V	Alternative VII
Price per head to Producer	115.5	156.0
Imports	54.6	-2.0

where the figures are per cent of base values. This table says that an <u>increase</u> in the price for imported cattle will <u>reduce</u> the quantity supplied - a backward sloping supply function.

In interpreting this table it is important to remember that "most of the (imported) animals enter (Venezuela) illegally through farm-to-farm transfer on the frontier", [5, p.421]. Thus a government policy of limiting import is not physically possible, since it would require a disproportionate, expensive and demoralizing effort by the Venezuelan army; nor can tariffs be collected on illegal imports: The foreign (principally Columbian) exporters can expect to receive essentially the on-farm price, and the model requires

a backward sloping supply function. A substantial increase in price for imported cattle is modelled as stimulating a sharp, and voluntary, reduction in these imports.

Inclusion of a foreward sloping import supply function would have moderated the domestic price rise, reduced the expected expansion of domestic production, and increased the foreign exchange cost of imported cattle .... nevertheless, most of the directional effects of the Miller-Halter analysis are presumably generally correct.

The problems of validation of simulation models has been well expressed by Miller and Halter [5].

> "Verification of a computer simulation model is not an easy task; the ultimate test of its validity comes in results from decisions made on the basis of the model. However, insight can be gained on the validity of the model by checking the logic of the model, by comparing computer results with historic data, and by assessing the model's predictive ability from a theoretical and/or common sense standpoint."

Using these latter criteria, the Venezuelan model must be judged invalid.

Despite this it convinced the relevant Venezuelan decision makers, in part, perhaps because of the confidence with which computer results were presented, and the good visuals used for their presentation.

> "Five variables - demand, supply, modern herd, total herd and traditional herd -

> were plotted on graphs to illustrate the impacts or increments that each policy or program had on each variable. These graphs were reproduced on 30 x 42 inch plastic overlays so that comparisons could be made between alternatives. These large graphs were used extensively to communicate the outcomes of policy alternatives to government officials, ministers, the country's president, and the news media," [5, p.431].

This may be a very important moral: Perhaps economists would find their advice sought more frequently if their analyses were less precise, but their presentations were more carefully prepared.

COLUMBIAN CATTLE MODEL

The Columbian Cattle Model is a considerable improvement over the Nigerian Model. It is only unfortunate that it was not developed in cooperation with national policy makers, so that the improvements could have been made in directions explicitly requested by decision makers.

Major improvements to the model include:

i) Biological realism has been improved by recognising three female cohorts and two male cohorts for each technology, as different from the simple male/female cohorts used in the Nigerian model. The female cohorts are young, breeding and old; the male are young, and finishing. A separate bull cohort is not maintained.

ii) Four modern technologies are examined in place of the one modern technology used in the Nigerian model. So far these four technologies have only been used for pairwise comparisons; traditional versus technology #1, traditional versus technology #2, etc. Thus no attempt has been made to find the right mix of technologies.

iii) Three, rather than one, ecological zones were defined.

iv) Sales are a function of both price and disease control programmes.

v) Some improvement in the handling of price formation. Both demand and supply are price elastic, but demand is a function of last periods price, so that the problem of simultaneous solution for price and quantity is avoided. Illegal exports are set at fixed levels (i.e. those exports are not price responsive), and legal exports are treated as a residual by the ingenious assumption that an export subsidy is paid to equate export price with domestic price. Fundamental changes to the model would be required, if the export subsidy was removed, or moderated, and export price became exogenous, or was modelled as being determined by an export demand function.

Numerous deficiencies remain. The most serious of which, is the feeling that the model may well have exceeded the data available.

Specific deficiencies which remain in the Columbian model are:

a) Mutual Exclusiveness of Development Opportunities: Four alternative methods of "modern" cattle production are specified, but adoption of these different modernisation approaches is treated as mutually exclusive. If one farmer opts for technology #1, no other farmer can develop using technology #2, #3 or #4. It is recognised [7] that the model could be modified to handle development using several technologies: But at present, only one development strategy can be employed at one time.

b) Weak Documentation of Development Alternatives: If the motivation for the Columbian Model is taken to be the development of a software package (without empirical content), then clearly this "criticism" is irrelevant - but the very limited scope of this software objective should be clearly recognised. Certainly the claim to empirical content is made [87]. This being so the description of modernisation technologies [67, pp.64-65] is clearly inadequate:

> "Modern Alternatives
>
> In considering the alternatives to traditional cattle production care has been taken to select those which embody a rather simple technology and are deemed to be both feasible and easily transferable given the resources at hand and the behavioral characteristics of ranchers in the Costa. Thus the alternatives considered are focused on investments in relatively simple improvements that will advance management and increase output. Outlays are spent on the most elementary of inputs: fences and stock water supply to permit the beginnings of managerial control; yards and corrals to offer the beginings of health protection measures; seeds and fertilizers to begin to increase fodder production.
>
> Since a major problem for cattle in the region is a lack of adequate dry season nutrition resulting in substantial weight losses, lower calving rates, higher death rates, and "delayed" maturation, the alternatives emphasize methods of increasing pasture production and growing and storing forage. These not only improve nutrition but also step up the average carrying capacity, allowing either for a larger or a constant cattle population in the face of expanding crops and shrinking pasture area.

The modern alternatives evaluated in the model are:

1. Pasture lands are kept with the grass species already present. Fences, stock water supply and corrals are established to pursue the beginnings of managerial control and health protection measures. Proper grazing rate and pasture rotation are introduced to increase fodder production and improve nutrition.

2. The same ranching practices as in Alternative 1 with artificial pastures substituting for natural pastures.

3. The same as in Alternative 1 with forage crops being used to provide feed during the dry season.

4. The same as in Alternative 2 with forage crops being used to provide feed during the dry season.

At the present stage of development of the model, the modern alternatives are not competing among each other for land and capital; they are evaluated in separate computer runs, each one at a time."

Since the dynamic nature of the model (in response to the tax, export and health policy tools) rests largely on the shift from traditional to modern production, one would have expected a careful illustrative budget/husbandry account of the technologies and their timing.

c) <u>Aggregation of Total Seasonal Feed Supply</u>:

To quote again [7, p.66] "Since the major problem for cattle in the region is a lack of adequate dry season nutrition, resulting in substantial weight losses, lower calving rates,

high death rates, a 'delayed' maturation, the alternatives emphasize methods of increasing pasture production and growing and storing forage." Despite this "major problem", TDN production in the wet season is not distinguished from TDN production in the dry season. Consequently, the model has minimum flexibility in its ability to consider strategies for filling this feed gap -- such as more seasonal patterns of cattle slaughter, irrigation, forage conservation, etc. Rather individual development strategies are developed which have <u>different</u> birth/death rate functions of TDN. The justification or documentation for these different production functions is totally missing. The production function is the same for all four modern development strategies [4, Figures II.4] - which seems highly implausible.

d) <u>Failure to Equate Supply and Demand</u>:

The sequential pattern of price formation is extremely complex:

Price (t) is a function of price in (t-dt) and the imbalance of demand and supply quantities in (t-dt), (Equation 7.2). Thus price is the key sequential variable allowing, as it does, a variable for <u>this</u> period to be expressed <u>exclusively in terms of variables which occurred in the previous time period</u>. Note, however, that this sequential price formation is bought at the expense of an unexplained inequality between total demand and total supply in each period. This point is

perhaps worth emphasizing. Equation (7.2) reads:

"(7.2) $$PA(t)=PA(t-Dt)*(1+\frac{Dt*C219*(TDEM(t-Dt)-SUPB(t-Dt))}{ELASD*\ TDEM(t-Dt)}$$

where

PA = Market price of finished males

SUPB = total Columbian supply of beef

TDEM = total demand for Columbian beef

C219 = model parameter

Dt = Time step for recursive relationships."

Fxports are included in TDEM so that we cannot rely on this quantity to provide a residual equality. The model simply specifies that in general:

$$q_s \neq q_d$$

where q_s = quantity supplied

q_d = quantity demanded.

Clearly, provided this inequality is kept "small" it can be interpretted as a measure of inventory adjustment. But validation of the model would surely require attention to these inventory adjustments, and it is reasonable to expect that such a sensitive assumption would have been clearly highlighted in the description of the model.

APPENDIX B

PERSONAL STATEMENT - CAVEAT

Any evaluation report can be read in two ways: in its "primal" sense as an evaluation of the project being evaluated; and in a "dual" sense, as an evaluation of the evaluator. To take the negative side, the biases and predjudices of the evaluator are, typically, as clearly revealed in an evaluation report as the weaknesses and deficiencies of the project being evaluated.

It is probably fair to say, that any careful evaluation report is likely to be "biased downward", in the sense that it is easier, and more ego-fulfilling to point to weaknesses of an approach, than to strengths. It is a big man who can simply say: I wish I had done that.

The logical formulation for the work of the MSU teams and their computers are exactly the same as for an extension worker with pencil and envelope: If these assumptions are true, then this conclusion follows. Adding detail and complexity to the model does not protect the authors from the retort: But those assumptions are not true! The numbers produced by the computer apply exactly to the computer model; they may or may not apply to the real world. The evident detail of the numerical results presented should not blind us to the very simple logical foundations on which they

rest. Furthermore, unfortunately, the logical validity of an if....then....argument, is as strong as the weakest assumption made. We create a logical chain, as strong as its weakest link. If for instance it is assumed that calving rate depends on total annual TDN per cow, when actually it depends on the distribution of this feed over the year; then this may be a fundamental error, which cannot be compensated for by additional assumptions elsewhere in the model. (Of course, if the assumption is correct, and total TDN is the important determinant of preformance, then further disaggregation to a seasonal basis of TDN availability, would add nothing. Any such differences of opinion on modelling approach, should be capable of being handled as technical questions, on which experts can agree, once the relevant data has been assembled.)

Let me admit to one bias, so that it can be corrected for, if it emerged in this evaluation report: quite apart from the MSU project, I believe that, in general, "simulators seldom know what they are doing." O.K., let me explain. By this I mean that simulators generally have difficulty in describing their model, qua model. Rather they describe their simulation program, but in so doing they lose the perspective of the structure of the system being modelled. Understanding of a model is greatly facilitated by simple statements of the type: "The following basic assumptions are made in this model:

i) Diminishing returns to feed supply,

ii) Perfect substitutability of feed with a year, zero substitutability between years,

iii) Non-stochastic coefficients,

iv) Individual decision makers behave competitively, etc."

Nomination of a particular production function, which shows diminishing returns does not tell the reader if this is an incidental, or an essential, feature of model structure. Yet it may determine whether the model has a unique global optimum, or several local optima. To retreat to the argument that "structure is unimportant, since we are using a general simulation approach", means that we cannot expect to learn from one application to the next, because we have no "structural" features of the economy (model) with which to associate our experiences.

An example of the tendency to describe a program, rather than a model is provided by pages 110 through 114 of [6] (see Appendix C) which could be replaced by:

> ""Birth and death" rates are taken to functions of annual TDN/animal. Linear interpolation is used for amounts of TDN/animal between the points in the production function nominated in Table 1.

TABLE 1: Birth and Death Functions Used in the Nigerian Cattle Model

TDN/ Animal	Birth/Rate		Death/Rate	
	Fulani	Hypothetical	Fulani	Hypothetical
<600	undefined	undefined	undefined	undefined
680	.06	.08	.55	.5
1020	-	-	.3	.17
1360	.19	.29	.22	.08
1700	-	-	.2	.06
2040	.27	.44	.14	.05
2380	-	-	.1	.05
2720	.33	.54	.1	.05
>2720	.33	.54	undefined	undefined

Note that no explanation is offered as to why the hypothetical cattle sector, which enjoys the same genotype as the Fulani cattle, should enjoy such markedly improved preformance - at the same levels of nutrition.

The question of the inputs which would be required to raise Fulani preformance to the level of hypothetical preformance is completely finessed.

To compensate, in part, for the downward bias which tends to creep into evaluations, let me make it clear that regardless of the merits of the simulation models themselves, the MSU team, have made innovations in the management

of teams of economists, and the carry through to publication of results, which are of fundamental, and beneficial importance in any thinking we may have of the amounts of economic resources which can profitably be brought to bear on future problems requiring economic expertise for its solution. This is a very valuable contribution in its own right.

APPENDIX C

Pages 110 through 114 of [6].

Beef-Milk Production Component

The beef-milk component was the first developed during the simulation project. Its purpose was to simulate cattle production in northern Nigeria and alternative means of improving it. The component is a complete model in its own right, containing an executive program which applies improvements to the traditional and (hypothetical) modern cattle populations of the regions.

Subroutine DEMOG

Using subroutines it was possible to simulate the behavior of both traditional and modern animal populations over time with one general model. Subroutine DEMOG performs this function in the beef-milk production component of the Northern model.

A subroutine of a program is to the model what a subsystem is to a system. It can be viewed as receiving certain inputs from the system model and supplying outputs which, in turn, are inputs to the system model. In the case of subroutine DEMOG, the primary inputs (from the Northern model) are:

TDNA = total digestible nutrients per animal (tons/animal-year)

SF, SM = sales of females and males, respectively, per year (thousand animals/year)

A number of parameters which determine birthrates, death rates, time delays, etc.

RFT, RMT = rate at which females and males are transferred from traditional to modern production sectors.

The primary outputs supplied by this subroutine are:

PF, PM = population of females and males, respectively (thousand animals)

DF, DM = deaths of females and males, respectively (thousand animals/year)

ER = extraction ratio (percent offtake) feasible at the given level of nutrition without changing population size.

An important attribute of this subroutine is that, given a set of inputs, a corresponding set of outputs will be computed. In this case, if "traditional" or "modern" inputs are supplied, "traditional" or "modern" outputs, respectively, will be computed. Thus, one subprogram can be used to simulate two or more subsystems which are alike in structure but differ in input and parameter values. This same concept was used repeated in developing the total model of which this component is a small part. In what follows, equations are numbered with a prefix indicating the component to which they relate.

Equation (BF1) of subroutine, DEMOG, computes the live birthrate as a function of level of nutrition.

(BF1) BR(t) = B41*TABLIE(VALB, SMALLB, DIFFB, KB, TDNA(t))

where:

BR = live birthrate--proportion of all females calving per year

TABLIE = a simulation subprogram which approximates arbitrary[22/] functional relationships by straight line segments

VALB = an array of numbers which defines the dependent argument of the function

TDNA = total digestible nutrients (tons per animal-year)--the independent argument of the function

SMALLB = smallest value of TDNA in the data which defines the function

DIFFB = the fixed difference between values of TDNA

KB = the number of line segments used to approximate the birthrate function

B41 = a model parameter (nominally one) which can be used to shift the birthrate function up or down.

Since birthrates in the traditional and modern sectors are different functions of TDNA due to different environmental conditions and management practices, the model includes the two birthrates versus TDNA functions shown in Figure 4.A.5(a,b). Equation (BF1), therefore, defines traditional or modern birthrates depending upon whether VALB is supplied with traditional or modern data. The data in Figure 4.A.5(a,b) are rough estimates based on available literature and conversations with animal scientists familiar with Fulani animals.

In like manner, Equation (BF2) computes traditional and modern herd death rates as a function of nutritional levels.

(BF2) DR(t) = B42*TABLIE(VALD, SMALLD, DIFFD, KD, TDNA(t))

where:

DR = death rate--proportion of total population dying per year

VALD = an array defining the dependent argument

TDNA = total digestible nutrients (tons per animal-year)

SMALLD, DIFFD, KD = as defined in Equation (BF1)

B42 = a parameter (nominally one) which can be used to shift the death rate function up or down.

Important in establishing this functional relationship is the concept of "maintenance TDN" or the level of nutrition required to maintain weight but no growth. Below this level of nutrition, starvation rapidly ensues and the death rate rapidly increases.

22/ This subprogram is a table-look-up algorithm which interpolates linearly between data points (Llewellyn, 1965).

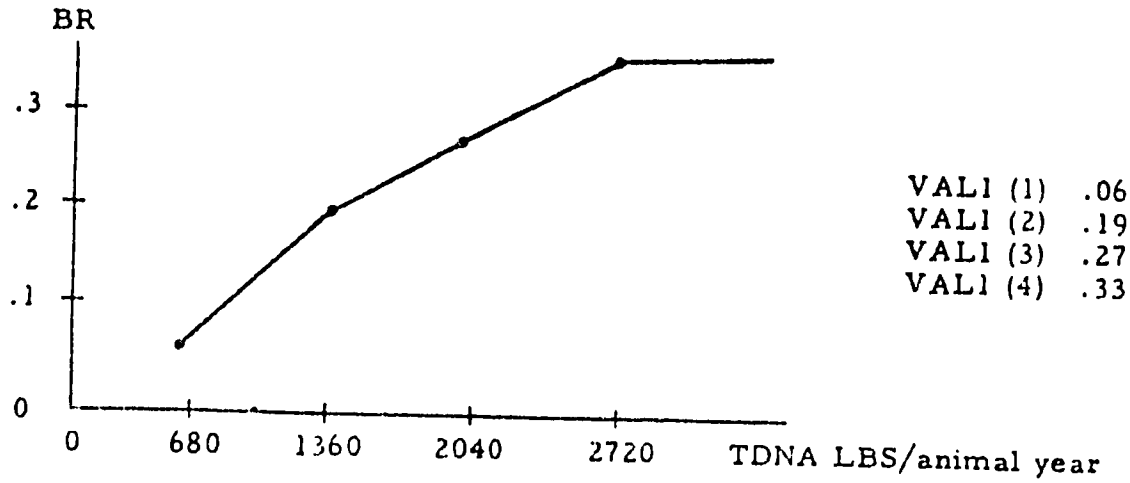

Figure 4.A.5.a. Traditional birth rate versus total digestible nutrients.

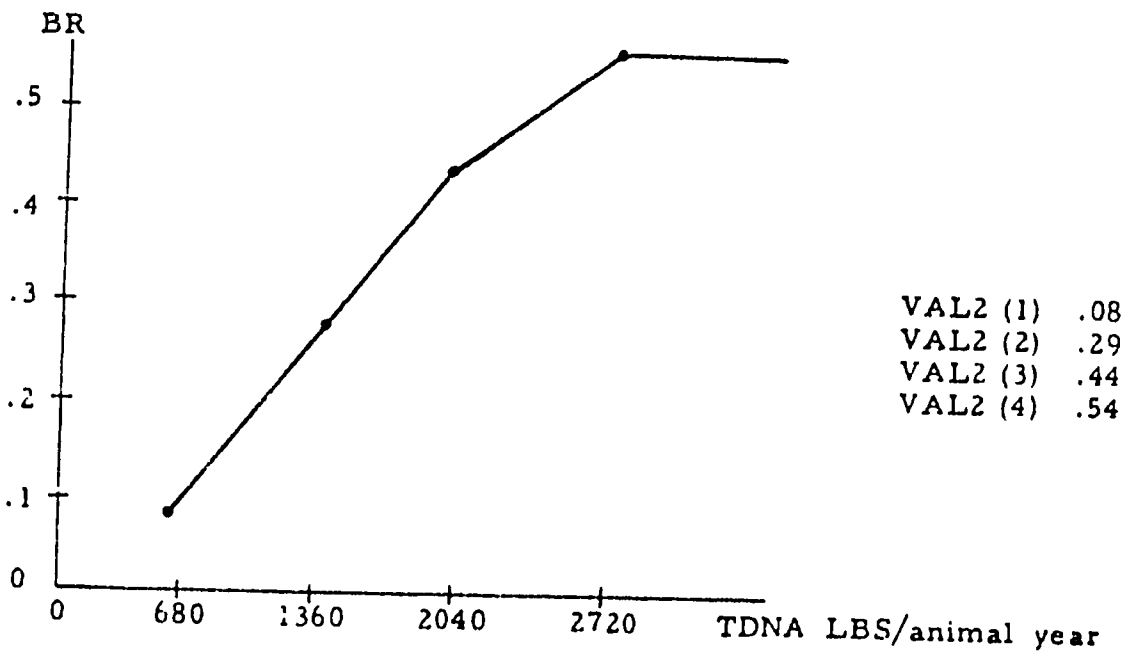

Figure 4.A.5.b. Modern birth rate versus total digestible nutrients.

In the model, a herd average level of maintenance TDN was calculated from estimates of maintenance TDN for various ages of Fulani cattle and data on the age distribution of Fulani cattle. The resulting herd average for maintenance was 1,360 pounds of TDN per animal-year. The death rate curves of Figure 4.A.6(a,b) were developed in consultations with knowledgeable animal scientists.

Equation (BF3) of subroutine DEMOG computes the extraction ratio or "offtake" feasible at various levels of nutrition.

(BF3) ERP(t) = PF(t)*BR(t)/(PF(t) + PM(t)) - DR(t)[23/]

where:

ERP = unlagged extraction ratio--proportion of herd that can be removed annually without changing herd size

PF, PM = number of herd females and males

BR, DR = birth and death rates as defined above.

Equation (BF3) is derived by finding the sales rate that will exactly balance the excess of herd births over deaths and dividing this rate by the total herd population.

In reality, births, deaths and extraction ratios do not change instantaneously with changes in nutritional levels and/or population sizes, but rather lag behind changes in these variables. The variables BR, DR and ERP must, therefore, be modified to introduce these lag effects. Equation (BF4) computes the auxiliary variable A1 used in a later computation related to the birthrate lag.

(BF4) A1(t) = BR(t)*PF(t)

where:

A1 = total live births/year--thousand animals/year

BR = proportion of all females yielding live calves per year

PF = population of females--thousand animals (recall that this subroutine can apply to either the traditional or modern herd).

In the case of animal births, introduction of an appropriate lag is somewhat more complicated than for deaths and extraction ratios. This is due to the fact that a natural increase in female population does not influence the calving rate for several years, but a natural decrease in population has a much more rapid influence (a delay approximating the gestation period). This difference in delay, depending upon whether the population is increasing or decreasing, is accounted for by Equations (BF5) through (BF10). Equation (BF5) computes an exponential average of A1.

(BF5) A1P(t+DT) = A1P(t) + (DT/.3)*(A1(t) - A1P(t))

23/ *This equation is based upon the assumption that male and female death rates are the same. Subsequent consistency runs of the model indicated that female death rates must exceed male death rates.*

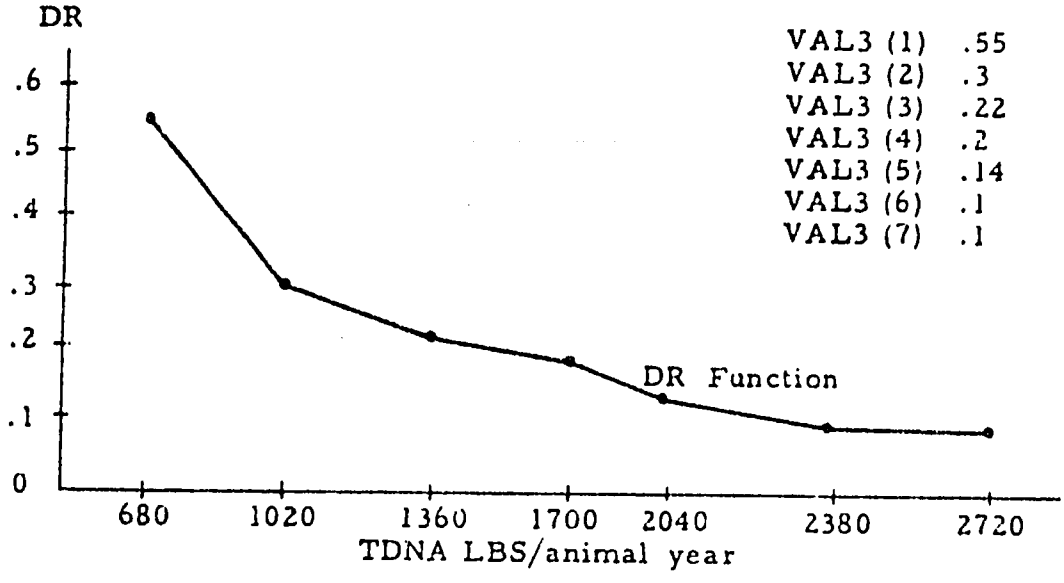

Figure 4.A.6.a. Traditional death rate versus total digestible nutrients.

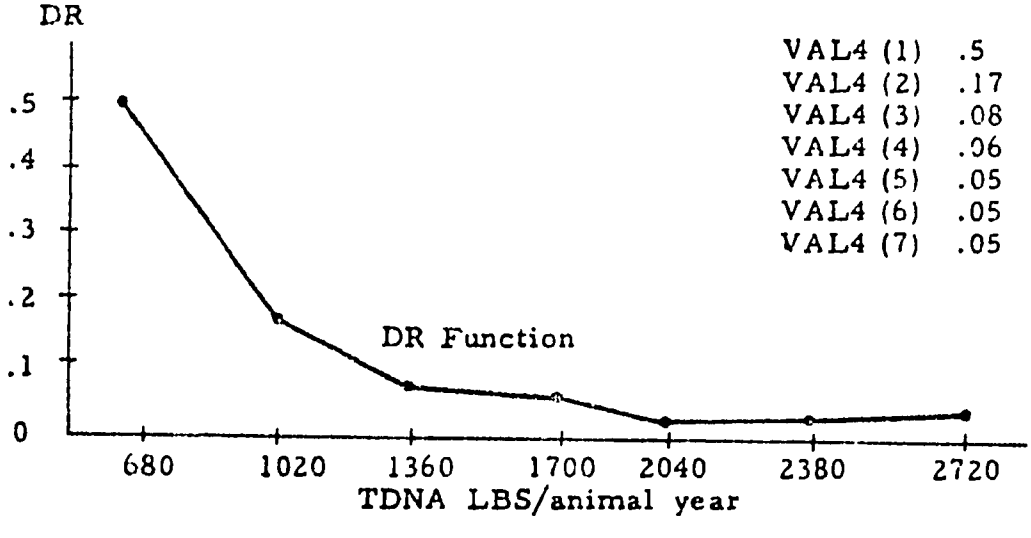

Figure 4.A.6.b. Modern death rate versus total digestible nutrients.