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# *The Importance of World Models for Agricultural Policy*

## 1. INTRODUCTION

This paper deals with three classes of world models

(a) international agricultural commodity models of the FAO-Gulbrandsen-type
(b) global world models of the Meadows-, Pestel/Mesarovič-, Linneman-type
(c) transmission models (LINK project)

The history of these classes of models is very different and also their contribution to decisions in agricultural policy. The global world models and the LINK models have been developed in recent years. The construction of models of these types can be expected to be one of the fastest growing disciplines in economics. The influence of the published models on decisions in agricultural policy is still rather low but this does not mean that the political influence of forthcoming models also will be low. Therefore, this paper also emphasises the future pattern in these fields. International agricultural commodity analysis has a longer history and, therefore, has had more influence on agricultural decisions.

The importance of economic models for decisions in agricultural policy is difficult to assess, especially for international agricultural models and decisions on international agricultural policy. Many world models would be much more useful for a centralised world government than they are for the decentralised national decision structure in the real world. Most of the decisions which determine the international agricultural scene are still done by national governments. National governments try to maximize the advantages for their countries – or for themselves. Their demand for information concerning the international agricultural scene differs from country to country. Countries which have rather small foreign trade compared to their GNP and total foreign

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trade find it rather easy to use various measures of national protection to avoid undesired influences from the agricultural world market. Countries which are main agricultural importers or exporters have much more interest in international agricultural developments. Their interests in information vary significantly with their import and export structures. Small countries are more or less price takers; large countries act like oligopolists or monopolists. The demand for information in western market economies differs also from the demand in socialist countries. To sum up, the need for information differs widely from country to country and model-builders should put more emphasis on this point than they have done in the past.

Most world models analyse long-run aspects but most political decisions deal with short-run or medium-run aspects. Therefore, this paper looks for possibilities to overcome this disparity. Transmission models seem to be a rather hopeful development. Various transmission techniques allow the linkage of complex national models to a more or less consistent international system. In future, it should be possible to build up transmission models which explain the interdependence between national economies on a rather high-aggregated level and also the interdependence between the national agricultural sectors on a rather low level of aggregation within one system, i.e. a system which includes also disaggregated models of national economies.

Transmission models so far have mainly dealt with short- and medium-run problems. The global world models of the Pestel/Mesarovič-, Bariloche-, and Linneman-type mainly create scenarios for the very long-run.

## 2. INTERNATIONAL AGRICULTURAL COMMODITY MODELS

### 2.1. *Surplus/deficit models*

The traditional and most used approach is the surplus/deficit approach. For each country and for each commodity the domestic produciton and the domestic demand are predicted separately, usually by simple trend methods. By countrywise aggregation of demand and supply projections future worldwide or regional deficits or surpluses can be estimated. In other words, the models point out expected shortages and surpluses for various countries and regions for the medium- and long-run future. In some models domestic demand is a simple function of the population and the per-capita income. Improvements of the supply predictions have been tried using simple supply functions which explain supply as a function of product and factor prices. Population, per-capita income and prices are exogenous variables. Models of this type have been built especially by FAO, OECD, and USDA[1] and have influenced the opinions of politicians and the public in general. The models do deliver a worldwide surplus/deficit scenario which enables us to locate critical points in food provision and they also give a useful starting point for the consideration of long-term market prospects. Secondly, the predicted trends help in discussing deviation problems together with stock statistics and also make a contribution to the analysis of short- and medium-run problems.

Critics of the trend models very often do not realize that accuracy is not the only criterion in valuing predictions. Valuation depends closely on the

purpose for which the prediction will be used. In the short-run they allow separation of trends and deviations to a certain extent; in the long-run they provide at least a starting point for the discussion of possible patterns of development and critical points.

The criticism of surplus/deficit models should be concentrated in two fields. Firstly, domestic supply and domestic demand are not sufficiently explained by economic variables. Secondly, the models do not explain how the difference between domestic supply and domestic demand can be closed by international trade or by variation of buffer stocks.

### 2.2. *Equilibrium and international trade models*

There are some extensions of surplus/deficit models which try to explain the difference between domestic production and domestic demand by world market models. The well-known Gulbrandsen model[2] is a simultaneous model with the following characteristics:–

– countrywise for each product there is a supply function and a demand function.

– the supply, as well as the demand, function show microeconomic characteristics. Supply of each commodity is a log-linear function of agricultural product prices, and demand for each commodity is also a log-linear function of all agricultural product prices.

– the price of the commodity j in the region i is by definition equal to the world market price of this good plus the price support of this good which is given by the nation i, plus transportation costs. Transportation costs per unit commodity are the same for each nation.

– Transportation costs and national price supports are exogenous variables.

By iteration the model can be solved in a way that results in a simultaneous price and quantity system which fulfils the functions and definition equations described above. In addition, the solution fulfils the market clearance condition for each commodity – that is, world import equals world export. The solution does not include a world trade matrix, so there is no information on what quantity of a commodity is delivered from one country to another. The model cannot give this information because there is no matrix of transportation costs and no other market share approach. The value of the model depends among others on the quality of the national demand and supply functions. Gulbrandsen includes these functions in a very schematic way. The microeconomic approach, and especially the supply and demand elasticities with respect to the agricultural product prices, are rather problematic. We will come back to this point.

The oversimplified transportation costs assumption reduces the value of the model, especially for those commodities which have high transportation costs or can only be stored to a limited extent. The crucial transportation costs assumption can be replaced by the so-called "transportation costs minimizing approach". Here an exogenous given transportation costs matrix, in addition to the described equation system, allows the building of an optimisation model[3]. The solution fulfils the condition that world imports equal

world exports for each commodity and, in addition, minimizes the transportation costs. Furthermore, this solution includes a world trade matrix. The formulation and solution of the model is rather easy for linear functions. In other cases the problem can only be solved by iteration.

The Gulbrandsen model, and also the spatial equilibrium models, are competitive models. Their national trade constraints are considered as exogenous variables, i.e., the price differences at the border are model input and not model output. In reality, however, many international trade constraints, especially the EEC levies, are functions of the difference between the desired domestic price and the price on the world market. The link between domestic prices and the world market prices is not as simple as it is assumed in the models described above. Furthermore, many exports and imports are the results of special government decisions which are out of accord with the principles of a competitive market. Irregularities in national buffer stock policy and concessional trade are also non-competitive elements. Especially in the agricultural sector it is unrealistic to make no distinction between price determination within a country or on the world market. Most countries want to achieve stability and continuity of prices and quantities within the national borders. This policy very often causes instability and non-competitive trade on international markets. The price equilibrium and trade models considered here given some hidden information which should be recognized. The models cover the main parts of international agricultural trade and provide a consistent price and quantity system. On the basis of this information it is quite easy to quantify deficits or surpluses in the national balance of payments caused by agricultural exports and imports.

### 2.3. *Extensions and modifications*

There are many models which are similar to the models described on the previous pages. Some concentrate on a smaller group of commodities or on just one single commodity[4]. Other models intensively work out the position of one specific country[5]. In the following we will concentrate on the problems of national supply and demand.

Many agricultural economists – as has been pointed out already – consider that high aggregated supply functions (estimated independently for each commodity by traditional methods of multiple regression analysis) only give very limited information. They believe that a satisfying explanation of the agricultural supply situation only can be worked out on the basis of disaggregated models which include farm structure, investment behaviour, expectations and decision functions of the farmers. The possibilities for explaining the supply in a better way vary from commodity to commodity and from country to country. To make use of these possibilities it is necessary to work with various approaches. Of course, this will make the models more complex and less comparable. But these more complex models can include also the relationship between the production of various commodities (e.g., joint production and joint investment, intermediate goods in the agricultural sector). Especially the relationship between agricultural supply and domestic demand in developed countries becomes more complicated from year to year, i.e., the processing

and distribution of agricultural goods becomes more and more important. The relationship between agricultural producer prices and domestic food prices changes in the short-run as well as in the long-run. There is also the problem of input/output coefficients. To overcome all these difficulties, it is necessary to formulate the so-called integrated agricultural development models which describe the total national agricultural sector in a consistent way. Models of this type have been presented by various authors[6]. Their core is usually a linear optimisation model which simulates the short-run decisions of the farmers. The medium- and long-term development of the agricultural production potential is included by various approaches; the nature of these approaches is either positive or normative. Many recursive and behaviouristic elements help to increase the stability of the model and to introduce common-sense arguments. There are various possibilities in setting up these models:

(i) the whole national agri-business can be included or only a part of it,
(ii) the degree of aggregation can be very different,
(iii) the models can be constructed with special regard to short term, medium term or long term problems.

Thus there is enough flexibility within the model for its structure to be adjusted to problems of special interest. From country to country the integrated agricultural development models are faced with different questions and facts (different economic systems, different production structures, different structure and intensity of foreign trade, different stages of economic development, etc.).

Integrated agricultural development models must be linked to the other national sectors and to international markets. The agricultural output sector has to be linked with various groups of demanders. Major problems arise in explaining exports and imports and the demand for storage. So it is necessary to incorporate the institutional frame and also some government variables.

Investment and labour input in the agricultural sector depend to a large extent on the situation in the other sectors of the economy. Supply of capital goods and the prices of capital goods are not only a function of the general domestic economic development but especially in developing countries, they depend rather strongly on foreign relationships.

Fertilizer input and fertilizer prices can only be explained when the international fertilizer situation is included in the model.

The sector of other inputs deals with four different input groups:

(i) commodity flows which are similar to intermediate commodity flows in the agricultural sector (for example, feed concentrates with ingredients produced by the domestic agricultural sector),
(ii) current inputs delivered from the agricultural sectors of other nations,
(iii) non-agricultural current inputs with low dependence on international economic relationships (local goods),
(iiii) non-agricultural current inputs with high dependence on international economic relationships (for example, fuel).

The inputs of group (i) and of group (iii) can be incorporated in the model

rather easily. The inputs of group (ii) and group (iiii) can only be endogenised when national and international models are included in the analysis.

Government policy in agriculture is hard to include in integrated agricultural models in a way other than as a set of exogenous variables. However, it is necessary to introduce government variables in the model in such a way that alternative behaviour of the government can be simulated.

The discussion of the borders between integrated agricultural development models and other national and international economic sectors shows that the information arising from these models can be increased substantially when the linkage to the surrounding sectors can be done successfully. Therefore, it is necessary to investigate the possibilities of linking the national agricultural development model to a macroeconomic model which includes the whole economy and to international economic models. It is difficult to define the most important limitations. In short-run analyses questions of investment and labour input are not so important, in long-run analyses the determination of the production potential plays the most important role. Very often more attention is given to the output markets than to the input markets. For many countries there are no reasons to look less carefully at the input side than at the output side. Especially in developing countries which import a major share of the agricultural input, the input side of the agricultural sector is at least as important as the output side.

The importance of national agricultural development models for the explanation of international agricultural product and factor markets has been analysed to a very small extent. This is understandable when we look at the history of these models. It begins with the analysis of the national farm sector on the basis of short-run linear programming models. Successively the models were extended to more complex models. It just seems to be a question of time before models are really linked with macroeconomic national models and international models.

In simple terms we have, at present, the following situation. On the one hand there are agricultural world models which explain in an oversimplified way the domestic supply and demand of agricultural commodities for most countries. On the other hand there are national agricultural development models which do not include relationship with other national sectors and to the world markets in a satisfying way. In the future it is necessary to connect both these developments in integrated schemes. In the following paragraphs we will discuss the possibilities and limitations of some approaches which may be useful starting points in this direction.

## 3. THE NEW SCOPE: GLOBAL WORLD MODELS

The Meadows model[7] initiated by the Club of Rome opened a new era in model-building. It produced rapid increasing interest in global world models concerning the future development of mankind. There are many reasons for this increasing interest and many of them have little to do with the professional economics. Nevertheless, the models of Meadows, Mesarovič-Pestel[8],

the Bariloche group[9], and Linneman[10] are very important models, just because important individuals and important social groups regard them as important.

3.1. *The Meadows model*

Meadows presents a high aggregated model with 6 stock variables and 4 flow variables.

Stock variables: reproducible capital, effective capital units per capita, population, land, exhaustible natural resources, level of pollution;

Flow variables: non-food production per capita, non-food consumption per capita, gross investment per capita, food production per capita.

These variables are elements of a very complicated non-linear dynamic system. Besides the definitive equations there are many behaviour and technology functions of different types. Meadows solved the non-linear system on the computer year by year up to the year 2100. He calculated a lot of alternative parameter sets. From the mathematical point of view the Meadows system is mainly a system of difference equations of a rather high order. Besides some very special cases, these systems show a large degree of instability. That is why a mathematician is not surprised at Meadows' results. Most of his results tell us that there will be a sudden break-down of the world economy, and a tremendous decrease of population in the next 100 years. On the other hand Meadows, and in more detail the Sussex group, have shown that there are special parameter constellations which lead to a continuous growth of the economy or asymptotically to a stationary state. These parameters do not look very unrealistic but on the other hand the model is rather sensitive even to small variations of the parameters.

The agricultural sector has a major place in Meadows' model. It is always dangerous to interpret a system in a very simple recursive way when the system has also simultaneous and feed-back elements. However, the conclusion is allowed that Meadows' agricultural sector is a highly simplified approach. The agricultural production function is quite difficult to understand and there is no explicit investment function. The assumed relationship between agricultural inputs and negative effects on land fertility is just naïve. Furthermore, pollution elements and the phenomenon of technical progress are rather weak points in the analysis. The main instability is caused by the following – growing population and growth of other factors lead to an expansion of arable land and to higher yields per acre. However, negative effects are caused with a certain delay – higher intensity and increasing pollution lead to a decrease in land fertility and to land erosion. From this a very sharp decrease in agricultural production results.

Many of the weaknesses in Meadows' model can be easily avoided. It is possible to improve the model substantially on a similar aggregated level[11]. Using the tools of modern growth and investment theory it is possible to set up a highly sophisticated model which could fit perfectly in the parade of the neoclassical growth models of the Samuelson–Solow-type. It is possible to analyse the relationships between the variables of interest in a neoclassical

model which is much more transparent than the Meadows model. Introduction of a production possibility frontier with the outputs pollution, food, non-agricultural goods and services and know-how, and the inputs labour, capital, land, and consumption of natural resources would be a large improvement. This introduction could help to discuss the partial influence of the determinants of long-run growth. These determinants are various types of technological progress, decreasing returns, various elasticities of substitution etc. To get a complete growth model there have to be added some dynamic functions (investment function, population function, labour supply function, accumulation function for technical know-how, and pollution reduction function). This model enables theoretical well-trained economists to analyse the conditions of balanced growth and to discuss various aspects of investment and technical progress policy. In general, these models are useful elements to train economic scholars in better understanding of the fundamental relationships in long run economics. Better understanding of these relations helps to avoid mistakes in applied economics analysis. However, the way from theoretical growth models to special predictions of long-term development is quite long. Looking at Meadows' model there are three crucial points: data problems, various questions of spatial distribution, the introduction of political and social elements.

Even a substantially improved Meadows' model will be rather sensitive to parameter variations. This results from the antagonism between technical progress and decreasing returns and from the various influences of assumptions on elasticities of substitution. That is why the result of model simulations depend heavily on the data input. Collection and definition of the data are rather difficult for the following reasons:

(i) in addition to other difficulties, there are the same difficulties which arise in the measurement of macroeconomic data on the national level,

(ii) there is little experience in collection and definition of high-aggregated world data,

(iii) for the set-up of the Meadows model, there are some unusual variables which must be defined and quantified (e.g., pollution).

(iv) it is difficult to estimate for the long run the exogenous variables of the model.

Nordhaus characterizes Meadows' analysis very concisely as "measurement without data". For various reasons it seems impossible to solve the data problem for high-aggregated models like the Meadows model in a satisfying way.

Models with an aggregation level similar to the Meadows model do not help to analyse the worldwide distribution problems; this is a serious disadvantage. The future of mankind is to a large extent a question of distribution:

(i) spatial distribution of world population,

(ii) spatial distribution of physical capital and know-how,

(iii) regional distribution of factor incomes,

(iv) world wide horizontal income and finance transfer, including capital transfer and foreign aid.

Political elements and social structures are not incorporated in the Meadows model. Models of the Meadows type offer only small possibilities of including government policy parameters. Perhaps it is possible to extend models of the Meadows type to normative models with the tools provided by the theory of optimal growth. Such an extension may be a useful addition to economic theory but there is no hope of their yielding further information which can be used in a direct way for political decisions.

### 3.2. *The Pestel/Mesarovič model*

Extensive discussion of the Meadows model encouraged the Club of Rome to sponsor another global world model. Pestel and Mesarovič tried to set up a model with the following improvements

(i) disaggregation of the world economy into ten regions,
(ii) disaggregation of the growth process by explicit introduction of more sub-sectors of production,
(iii) extension of the model by introduction of decision-functions and learning and information processes.

The Pestel and Mesarovič group put much emphasis on the collection of worldwide data. As far as possible, they made the data comparable and integrated them in a large system of definitive equations. The importance of this statistical work should not be underestimated; I have the feeling that it would be worthwhile to continue it.

Pestel and Mesarovič tried to present a global and disaggregated world model. This target has not been achieved. They have not presented a model which simulates the worldwide growth process and the growth process in the various world regions simultaneously. To achieve this a very complex model must be available and such a model cannot be built in two or three years as Pestel and Mesarovič tried to do.

These authors present partial analysis; they analyse the energy problem, the problem of foreign aid, the problem of some non-renewable resources, and the food problem. The food problem analysis will be described in the following.

The methods in this analysis are rather similar to the methods Pestel and Mesarovič used to analyse the other problems mentioned above. They take the line that, in the long run, the food problem will be most serious in South Asia. Therefore, they concentrate their analysis on this region. Food needs per capita and population growth are estimated for the long run by common methods. The food supply from South Asian agriculture is explained by an implicit production function; technical progress, current inputs, land and capital stock per acre are the main variables. The estimation of the production function is based on production curves and developments which have been observed in the developed world in the past. The linkage between the agricultural model and the non-agricultural sectors is less intensive than in the Meadows model. The Pestel/Mesarovič model does not have an extremely complicated feedback structure and therefore the growth paths of this model

are much more stable. Commonsense arguments have major importance. Pestel and Mesarovič simulate some alternative developments.

The first scenario is, to a large extent, a simple trend analysis. It shows that in the period dated from year 2000 up to year 2015 about 500 millions of people in South Asia will die because of lack of food. The second scenario shows that the problem of hunger in South Asia cannot be solved even when the developing world gives maximal food aid to South Asia, if no other change of policies is assumed. The third scenario shows what happens when the countries in South Asia re-allocate their resources from the non-agricultural to the agricultural sector. If there are no other changes in economic policy this re-allocation only improves the food situation in the medium run. In the long run the reduced growth in the non-agricultural sector causes reduction of input in agriculture and this reduces food supply. Other scenarios investigate the influence of alternative reductions of the fertility rate and combinations of various methods. Finally Pestel and Mesarovič present – in their own opinion – the "best" scenario. In this scenario the developed countries give their foreign aid to South Asia mainly in the form of capital goods. These capital goods improve the agricultural and non-agricultural productivity in South Asia. Food production and export/import potential is increased in such a way that the problem of hunger can be solved.

There are some important characteristics of the Pestel/Mesarovič model. The selection and handling of the problems happen in a very pragmatic way. They concentrate their work on a few relationships which seem to be important. They investigate only selected possible development paths without using complicated methods. They select the "best one". This procedure seems to be very subjective and there is the danger of neglecting other important factors. Economists have some trouble when they try to make statements about the usefulness of the Pestel/Mesarovič scenarios. On one hand there is the feeling that most of the results they present are not new, at least not new in terms of quality. On the other hand, the quantitative results of Pestel and Mesarovič are quite impressive. The problem is the extent to which we can trust these quantifications. The publications of the Pestel and Mesarovič group do not give a sufficient basis for checking the quality of the published results. There are good reasons for doubts.

Firstly, the group must have had the same problems as other economists in estimating the food supply in South Asia. To achieve substantial improvements in supply analysis it is necessary to set up rather complex national agricultural models. This has been mentioned earlier in this paper. Secondly, the Pestel/Mesarovič group had to solve very difficult trade-off problems. The estimation of the trade-off between the agricultural and the non-agricultural sector in the form of a production possibility function has not been solved in a satisfying way up to now. Furthermore, Pestel and Mesarovič have been faced with the relationship between import/export structures and sector productivities. Let us assume that they have solved all these problems better than other economists before them. The question then arises to what extent the best Pestel/Mesarovič scenario influences economic and agricultural policy. Most of the politicians have no general objections to this scenario and favour

(i) more foreign aid for South Asia,
(ii) foreign aid for South Asia mainly as transfer of capital goods and know-how,
(iii) food aid for South Asia only in cases of emergency,
(iv) measures which help the developing countries to achieve larger market shares for industrial goods on the world market.

The real problem is to realize these general aims, that is, to find operational procedures. Pestel and Mesarovič do not suggest those procedures. Their scenarios cannot give the necessary answer, because of the global and extremely long-run orientated character of their model. These scenarios are more helpful as a basis for general discussions than for detailed political decisions.

### 3.3 *The Bariloche model*

A research group in Latin America is working on a global world model called the "Bariloche model". The work is still going on and there is not much published information about the model and the results. The following remarks are based on a discussion from Nordhaus[12] and some other information.

The Bariloche model puts large emphasis on the situation in the developing world. The world economy is divided into one developed region and three developing regions (South Asia, Latin America, and Africa). Little attention is paid to the international economic relationships between these regions. For each region there exists one model. The characteristics are the following. The model contains much more normative content than the previous global world models. The, so-called, "basic needs" play the leading part. There are four categories of basic needs

(i) calorie intake per capita must exceed 3000 per day,
(ii) at least 98% of the population between 6 to 12 years must be enrolled in schools,
(iii) each family must be provided with a house of minimum quality,
(iv) other substantial consumption goods (e.g., health service)

The per capita utility is described by a very unorthodox utility function. The variables of the utility function are life expectancy and surplus consumption, defined as the consumption which exceeds the basic needs. The production possibilities of the region depend on labour inputs, capital stock, and natural resources. The production technology is described by sectoral Cobb–Douglas functions. Technical progress as defined in modern production theory is excluded. There are five production sectors. Four of them produce consumption goods and one produces investment goods. The utility function is maximized under the constraints given by the technology and the available inputs year by year. It seems that there are further constraints in this maximization which predetermines the level of investment. Anyway, the model shows an investment rate of 20–25%. Population growth is an endogenous variable. It is assumed that the population growth rate decreases when per capita income increases. At least, this assumption is correct when the basic needs of the population are satisfied.

The complete model allows two alternative classes of growth paths depending on the parameter constellation. If there is sufficient growth of the surplus consumption in the initial phase, the population growth rate decreases. Then the total regional demand for basic needs grows less fast than the GNP and this process continues in the direction of a developed country (balanced growth or an asymptotic approach to a final stationary state). If, in the initial phase, surplus consumption decreases or does not increase enough, the population growth rate increases. Then the surplus consumption decreases continuously to zero. The downward movement does not stop here because the per capita income decreases still further. Finally, the process leads to a Malthusian situation. The available information can lead to the conclusion that the Bariloche group has formulated the model for central planning economies. In most of the developed countries the provision of the basic needs can only be achieved by central planning means which enable a very nearly equal income distribution to be reached.

The model runs show that Asia and Africa will have a decrease in per capita income in the way described above. Only if the developed countries give substantial foreign aid in the way of capital goods to these regions will there be a take-off. The importance of the Bariloche model for agricultural policy cannot be analysed due to the lack of information. However, it seems to be a heroic approach to explaining the world food situation without taking into consideration the worldwide trade in agricultural goods.

3.4. *The Linnemann model*

Sponsored by the Club of Rome a research group in the Netherlands (since 1972) has worked on a project called "Food for a Doubling World Population". The final results of the project are to be published in 1976 ("MOIRA – A Model of International Relations in Agriculture", North Holland Company), The project leader is Dr. Linnemann and, therefore, the project is known as the Linneman model. It deals only with the world food problem. Nevertheless, it is useful to put this model into the class of global world models. Results from this project are not yet published; the basis for the following comments are some unpublished papers presented by the Linneman group. Their main aim is to analyse the world food problem up to the year 2010. It is assumed that up to the year 2000 the world population will double. Linneman analyses domestic food supply and food demand country by country. The quantity of food supply and demand is measured in terms of protein. Linnemann believes that this index is a better measurement than the usual grain equivalent approach. Per capita consumption of food is a linear function of per capita income. Linnemann takes into account various income classes; the national demand function for food is derived from the demand functions of various social groups. National income distribution and the growth of population are exogenous data. The main emphasis is put on the supply side. Linnemann tries to estimate the upper limit of food production for each country; roughly speaking, this is the level which cannot be exceeded without revolutionary new basic inventions. This upper limit provides 40 billion people with food under the condition that food is equally distributed

and the basic needs are satisfied. The national upper limit of food production is an important element in the national production function for food. The production function furthermore includes the variables labour, land, capital, and fertilizers. Linnemann has estimated the parameters for the production function on the basis of cross-sectional data. The information I had did not tell me to what extent Linneman incorporated product and factor prices in his analysis and what are the determinants of these prices. In his summary paper Linnemann gives the impression that he has incorporated an endogenous world-wide price system and important action parameters of governments also.

The Linnemann group presents in the summary paper some results of the model, e.g., some tables which describe food production and food demand for the regions North America, EEC, Latin America, Tropical Africa, Middle East, Southern Asia, and the world in total , for the period from 1975 up to the year 2010. Each table describes a development which will take place when certain assumptions are fulfilled. The main determinant for the development is the economic growth in the non-agricultural world. High non-agricultural growth leads in all cases to a higher level of food consumption per capita in almost all regions. For the assumption of high non-agricultural growth as well as for the assumption of low non-agricultural growth Linneman analyses the influence of various strategies of agricultural policy. He considers unchanged policy, moderation of food consumption in rich countries, food aid on a large scale by the rich countries, high and low world market price levels, and some combinations. Surprisingly, the strategy "unchanged policy" compared to other strategies leads to a rather good world-wide food situation. No strategy really improves the per capita consumption in South Asia. The results which are described in the summary paper presented by the Linneman group seem not to be based solely on the tables referred to. Anyhow, the existing information gives the impression that they have analysed the advantages and disadvantages of various strategies very carefully. To what extent the interpretations are really outputs of the Linnemann model and to what extent other considerations are important, is not absolutely clear. In the following we repeat some of the Linnemann theses:

(i) A decrease of economic growth in the developed world and also a decrease of food consumption in these areas has negative effects on the food situation in the developing world.

(ii) If the developed countries spend 0.6% of their GNP every year for food aid for the developing countries hunger in the world can be reduced to nearly zero up to the year 2010, at least when distribution is managed in an optimal way.

(iii) A liberalization of international agricultural trade has negative effects on the food situation in the developing world. The reason for this is a world-wide reduction of food production caused by the liberalization.

(iv) A stabilization of world market prices at a high level achieved by measures operated by the developed countries is an important improvement compared with the current policy in the opinion of Linnemann.

We have to wait until the Linneman group proves that their considerations for long-run policy measures are based on excellent investigations.

3.5. *Some remarks on the meaning of long-run global world models*
The history of long-run global world models is too short for us to be able to come to a final conclusion about the meaning of these models. However, already today some limitations are obvious. The effort to present a world model which incorporates all main economic activities in the world on a very high aggregated level has failed. At least, these models are not relevant for actual economic policy. That is why Pestel/Mesarovič and, especially, Linnemann analyse partial worldwide problems on a lower level of aggregation. They do not put as much emphasis on inter-sectoral linkages or bottlenecks caused by non-renewable resources and pollution as Meadows did. But their models also do not include real political and institutional elements; especially national problems are not part of the models.

A large part of the model analysis is concentrated on the deduction of long-run growth limits in the technologic field. These analyses seem to be rather useful. They can give incentives to governments and other institutions to formulate or reformulate long-run programs in research and development. For various reasons allocation of resources is much more imperfect in the social sense in the so-called "technical progress production" than in the ordinary production sectors (higher degree of monopoly, more externalities, higher degree of uncertainty, larger time differences between input and output). The models do not give many hints concerning the international division of labour. There is a large demand for these hints from politicians throughout the world. It should be clear that the factor capital and the factor labour, too, are not distributed in an optimal way, at least not in a way which leads to a maximization of world production. International trade, too, is not optimal. It is really necessary to get more insights into the limitations and possibilities of international capital and technology transfer. Probably most of the limits arise from institutional constraints. It would be useful to show the social opportunity costs of their nationalistic economic policy to some politicians. A large international capital and know-how transfer and the transfer of consumption goods, too, are related closely to questions of transfer of international finance. In this field it is necessary to develop new world-wide scenarios which include also institutional variables.

## 4. TRANSMISSION MODELS

4.1. *The LINK project*
Up to now we have discussed world models dealing with long-run problems. It seems to be impossible to extend these models to short-run and medium-run models. It is difficult to set up a world-wide disaggregated short- and medium-run model. There are suggestions that we should start with a world-wide input/output matrix[13] and develop a model on this basis. However, in practice the set-up of a world-wide Walrasian model seems to be an illusion. On the other hand there is a growing interest in the so-called "linkage models" in

the past year. World-wide linkage models consist of national models linked together. These models have several advantages:

(i) many national models are already available,

(ii) the national models can differ to a certain extent from country to country. This gives a chance to incorporate country-specific situations.

(iii) the world models can be set up in a decentralized way. Every nation presents its own model and the world model-builders link them together.

The interdependence between national business cycles has especially been forceful in convincing many economists that it is necessary to link national models together. Many countries have macroeconomic models for the short- and medium-run. These models differ in many aspects (level of aggregation, time horizon, quarterly or annual data, incorporation of the monetary sector). Exports and imports are explained by export and import functions. In most cases the export quantities are functions of the world trade and the relation between domestic prices and world market prices. The amount of imports is a function of national income or similar variables and of the relation between domestic prices and the world market prices. World market prices and world trade are exogenous variables in the national models. Exports and imports, and also the prices calculated and predicted by the national models, are not consistent in the world-wide sense. The consistency in the world-wide sense is given when the sum of all world imports equals world trade, the sum of all exports equals world trade and prices expressed in dollars and calculated on f.o.b. basis are the same from nation to nation. The LINK group[14] is working to achieve this world-wide consistency. They have developed some iteration techniques which lead to this consistency. In the iteration processes world trade is varied until consistency is achieved. Some iteration techniques secure only the consistency of imports, others the consistency of exports, imports, and prices. Some approaches result in countrywise consistent exports and imports, but no consistent results are achieved for the trade flows between different countries. Other iteration techniques calculate a world trade matrix on the basis of a constant market share approach. "Perfect" linkage techniques are not yet available, but the considerable progress in developing new techniques in the last few years gives us hope for the availability of much better techniques in the near future.

The LINK group tested its model for the first time in 1971 to get preliminary results. An extensive analysis was presented in 1975. The linkage of national economic models as it is done by the LINK group in Philadelphia, has attracted much attention from experts who are involved in employment and monetary policy. Up to now, the LINK model has delivered simulations for four years. But, as Klein pointed out, it is possible to do simulations for a period of 6 to 7 years. Such a time horizon is long enough for many decisions in economic policy. The LINK project is a long-term one; in the coming years some bottlenecks have to be overcome. National models must be improved; especially the monetary sector must be incorporated. This incorporation of the monetary sector allows the construction of a linkage model which explains capital flow and balance of payments and exchange rate problems. The LINK

models have a rather high aggregation level. There are only four production sectors; one is the agricultural sector. It is well-known that it is rather difficult to build up a satisfying multi-sectoral business cycle model, but on the other hand we can expect that in the next years models with 4 or 5 production sectors will be available for many countries. The incorporation of normative elements and policy parameters has to be pushed forward, too.

The success of the LINK group mainly depends on three components

(i) development of linkage techniques,
(ii) development of national models,
(iii) administrative and financial constraints.

The development of new linkage techniques seems not to be the main constraint. The development of national models takes a lot of time. These models must be available at a central institute to be calculated there. This central institute needs all exogenous data as early as possible. This is necessary to ensure that the calculations can be done in time. To a certain degree the work of the national model builders has to be coordinated. However, the basic principle of the LINK approach is that the nations themselves know their problems better than a central institution and for this reason they should build their own models.

4.2. *LINK approach for the agricultural sector*

For the near future there is little chance to disaggregate the national short- and medium-run models in such a way that many production sectors can be considered explicitly. In the future, we will perhaps have national economic models with 4 or 5 production subsectors for many countries – and one of these subsectors will be the agricultural sector. That is why the linkage of national economic models can deliver only rather global insights in the world-wide agricultural relationships. For more detailed insights there is a need for a disaggregated world-wide agricultural model. For a world-wide linkage of disaggregated agricultural models with national models it is necessary to work with a multiple LINK approach. Figure 1 shows the basic idea. Every nation presents a national economic model with 4 or 5 sectors, the agricultural sector in this model is the result of an aggregation of a more detailed agricultural model called "disaggregated national agricultural model". This disaggregated national agricultural model can be of the Day/Heidhues/de Haen type. The national economic models can be different from country to country. They can be linked together by using one of the available linkage techniques. In this way, we get solutions of global national models which are consistent on a world-wide scale. At this stage it is possible to introduce some corrections and to solve the system again (i.e., modifications of policy parameters). The final solution of the national models also delivers aggregated national models which are of world-wide consistency. These models are the starting point for a disaggregated analysis of the international agricultural situation. The regional disaggregated national agricultural model is solved within the framework which is given by the solution of the aggregated national agricultural model. This has to be done for all national agricultural models. The disaggregated

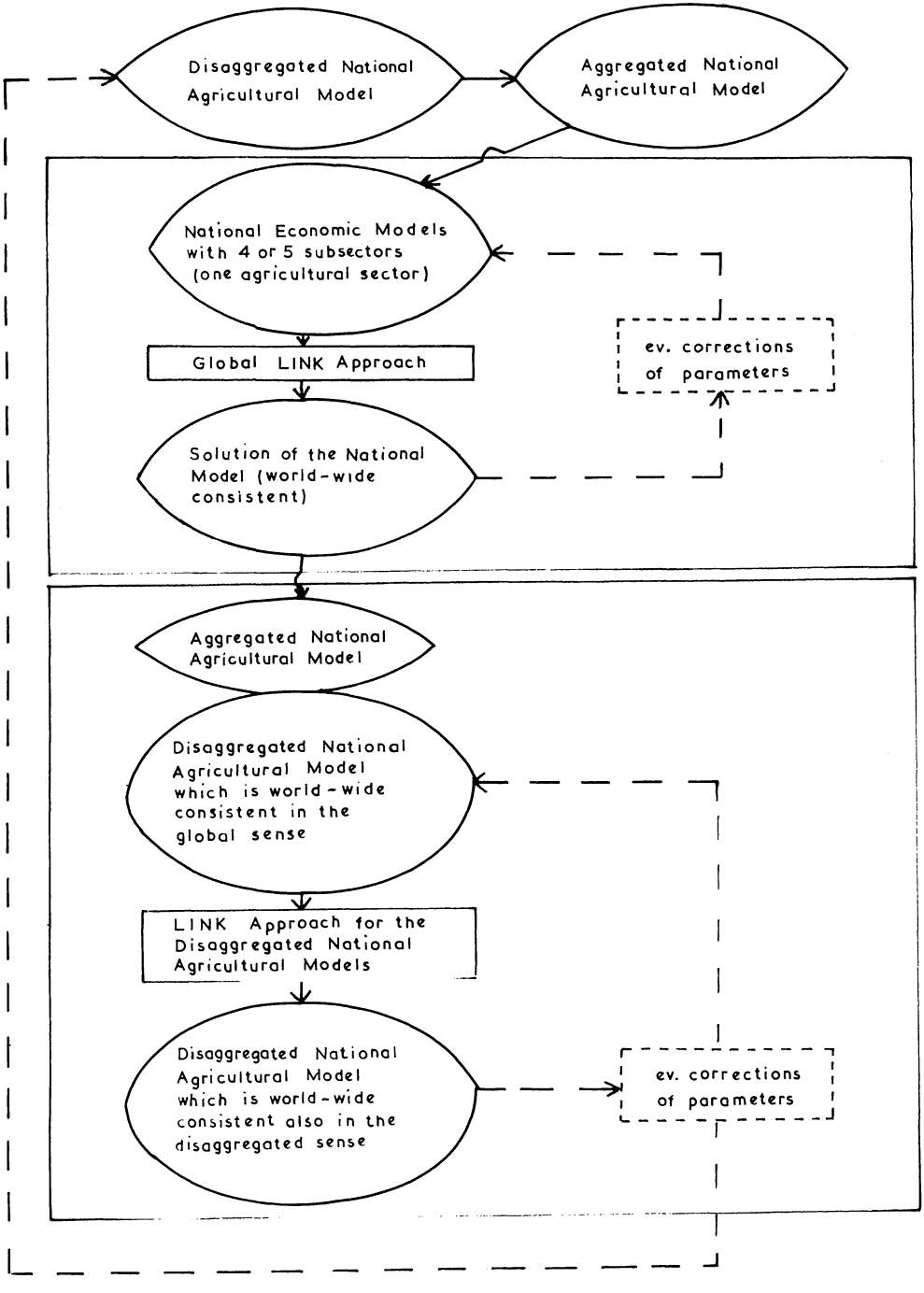


FIG. 1. Multiple LINK approach.

national agricultural models calculated in this way are consistent world-wide with respect to aggregated exports and imports but not to disaggregated exports and imports. To get consistency on the disaggregated level, too, the LINK approach is used. The results are disaggregated national agricultural models which are also consistent in detail. The solution of these models can be considered as the final solution of the multiple LINK approach. However, further calculations may be useful. It is possible, that various parameter variations, including government policy variables, may look quite unrealistic. Two corrections can be made. Firstly, it is possible to solve the disaggregated models again for the new parameters without attention to the relationships with the non-agricultural sector. This approach may be sufficient in many cases. Only in cases in which we have to expect that parameter corrections in the agricultural sector will have an important influence on the whole economy it is necessary to repeat all stages of the multiple LINK approach. The LINK approach for the disaggregated agricultural models in principle is confronted with the same difficulties which arise by the global LINK approach. However, there are some additional problems. More microeconomic elements have to be incorporated (price elasticities, special characteristics of the agricultural markets, etc.). Also government regulations must be incorporated in a more detailed way. The outlined scheme is rather flexible in the way that models can be modified in different ways according to the problems which are of interest.

The multiple LINK approach looks rather complex. However, current developments in model building are going in this direction. Most economists agree that it is necessary, and possible, to continue the development of national economic models which include 4 or 5 production sectors. Most economists, too, favour the set-up of integrated agricultural development models for all countries. The collaboration between national model-builders and agricultural economists has not been very close in the past but the situation is beginning to improve. Recent discussions have shown that a closer cooperation in model-building is necessary and is desired.

Of course, there are differences from country to country. In highly industrialized countries it is possible to explain major features of the economic development without a detailed consideration of the agricultural sector. In developing countries the opposite case will be relevant. The global LINK approach will be used to a much larger extent and the interest in world-wide consistent agricultural models is also growing. Therefore, the prospects for the multiple LINK approach are rather good.

The contributions of multiple LINK models to agricultural policy, as described above, can take place in various ways. Short- and medium-run national aggregated agricultural models which are linked properly to the other national sectors and also to the world-wide scene will gain more and more interest for institutions which give governmental advices. In recent years decision-makers in agricultural policy have realized that it is impossible to set up an optimal agricultural policy without considering the relationships to other parts of the national economy. Furthermore, international agricultural problems influence national agricultural policy at present more than in the

past. Especially developing countries with a high intensity of agricultural foreign trade have to take into consideration world market situations when they make up their national development plans. The patterns of exchange rates, balance of payments, and business cycles influence strongly the prospects of their agricultural sector and their national food supply, especially in the developing world. Most failures in agricultural policy have arisen because decision-makers in agriculture do not have enough informations about the surrounding sectors. It should be possible to present the results of the multiple LINK approach in such a way that the decision-makers in agriculture get more and more interested in intersectoral and international relationships. This is a necessary condition for an impact of multiple LINK models on political decisions. Learning processes will take place and, finally, decisions will be influenced by these models. The advantage of the multiple LINK approach is that some of its elements, especially the national parts, have already an important influence on political decisions. The new parts are just extensions and therefore, learning step by step is possible.

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## DISCUSSION OPENING – C. Thomsen, *Denmark*

Professor Richter's paper is instructive and down-to-earth in an area which is so wide and complicated that it is easy to be carried away into highly sophisticated considerations. The complexity of the subject may be illustrated by the remark that world-wide decision-making in agriculture is a rather nebulous concept and international trade models are hard to find, to use an analogy applied to the New Economic Order.

Among the different levels of decision-making dealt with at the Conference, the one at the international level may be considered to be of the highest order. But I agree, that there is a tendency to limit decisions to areas and measures which can be controlled in the framework of a national policy, or a common policy as in the EEC. Unfortunately such decisions often have repercussions for other countries and for international trade, i.e. the so-called beggar-thy-neighbour policies. There is thus a growing need for concern about decision-making at the international level, and the subject seems worthy of more attention than it has received at the Conference.

The complexity of decision-making in the EEC has been well illustrated in Dr. Tracy's paper, and anybody who attended the UN World Food Conference in 1974 should agree that it would be extremely valuable to have an analysis of the decision-making that took place on that occasion. Although behavioural science is on the border-line of the discipline of economics, there is an obvious challenge in its application to international governmental organisations. Some work has already been done, but with the advent of the New Economic Order the need for a better understanding of the machinery involved will be even more pressing.

As regards examples of international trade models, Professor Richter has referred to the OECD projections and the FAO perspective studies. But in my view these studies could not be called trade models proper. As the paper points out, they only deal with international trade as residuals or balances resulting from projections of aggregate production and consumption in individual countries and regions. In a trade model worthy of the name the trade issue, with attention to prices should have a central position in the analysis. The paper makes reference to the deficiency of the studies in this respect and to the difficulties in obtaining reliable price elasticities both for supply and demand. But these difficulties could not diminish the importance of prices and price signals in any model dealing with trade. Without going into the other difficulties in connection with the setting up of international trade models referred to by Professor Richter, it seems worth making the point that some of the major criticism of the operation of the world market in agricultural products has come from quarters which have, themselves, contributed to

the worsening of the situation by limiting its scope of operation still further.

With regard to the interrelationship between product studies, country studies and trade models, Professor Richter has emphasized that the problem of the quality of data becomes the more serious the more aggregated is the model. But if we want to work out realistic models, we cannot escape the need to integrate commodity studies into agricultural sector models, both nationally and internationally. The same applies to the integration of agricultural sector models into models for the total economy, and finally to the eventual integration of countries and regions into a world model. In my view, this can best be done through a step-by-step procedure, the same way as macro-models gain from being based on micro-models, and I find the exploration of possibilities of linking various models together very promising. Also in this context, prices will have a central role to play in the process of linking models together and providing for the necessary feed-back between them. This subject is described in the following paper by Professor Scheper.

My final point is concerned with the possibility of, in fact, using trade models as a base for world-wide decision-making. Although there is a growing need for this the experience of the past in international organisations leads to a great amount of scepticism. The predictive value of existing models has proved to be very limited and although the suggestions of Professor Richter for the inclusion of additional non-quantifiable parameters and factors, i.e. of institutional and political character, may improve their ability to explain the past I cannot see that this could improve their predictive value. The stochastic character of some of these variables, referred to earlier in the Conference, should support this view.

However, although I am sceptical about the direct value of these models for decision-making, I find more reason for optimism about their educational value. Apart from their value in university education, I also believe that they can play an important role in the education of the politicians. Here lies a challenge to agricultural economists and research institutes, both at the national and international level. International organisations no doubt also have an important part to play in the education of politicians but, so far as model-building as such is concerned, this task should preferably be entrusted to the independent research institutes.

## DISCUSSION OPENING – A. S. Watson, *Australia*

Dr. Richter's indecision about the usefulness of formal models in predicting world trade in agricultural products makes it difficult to comment on this paper. In the early part he is sceptical about such models and there appear to be good reasons for this, particularly with respect to models like those of FAO which he discusses. More recent development in trade modelling may overcome some of the problems, but there are still good reasons for agreeing with the scepticism of Dr. Richter's introduction.

When only a small proportion of world production of a commodity is traded, it is inevitable that fluctuations in supply will change the status of

countries, or groups of countries, that aim at self-sufficiency, from being net importers and net exporters. Quantities entering world trade, and world prices, therefore, are inherently unstable.

In the conclusion to his paper Dr. Richter suggests that international organisations put more resources into formal forecasting. This must reflect a judgment that efforts so far have been worthwhile, either for prediction or for qualitative analysis of trends revealed by formal models. In my opinion, the latter use of models is more acceptable.

My comments concentrate on specific points, but I would like, first, to refer to an important deficiency of the paper. There is no mention of the need to revise the approach to trade modelling in a world of flexible exchange rates. It is no longer sensible to separate agriculture from the rest of world trade and the world economy in model-building. To me, at least, this is a serious weakness of the models he has described; the current generation of trade models is considerably in advance of the models to which he has referred.

International trade in agricultural products will not, in itself, solve the world food problem. Expanded trade would assist in the process of income generation necessary for capital accumulation in developing countries. With respect to the food problem, trade in grains can help meet shortfalls in domestic production. The remainder of agricultural trade is either in commodities like sugar, coffee and tea – which are not generally described as food – or in agricultural products like the natural fibres which are industrial raw materials. In addition there is the trade in livestock products which is essentially restricted to developed countries because of the substantial investment required in the marketing infrastructure.

At the start of his paper Dr. Richter asserts that it was taken for granted in the 19th century that the instruments developed to facilitate trade functioned perfectly. This is a considerable over-simplification of economic history – to put it mildly. Later Dr. Richter refers to the fact that nowadays a greater percentage of world trade takes place outside traditional marketing systems. Most bilateral arrangements cannot be called "non-market" as they require information provided by commodity markets.

Dr. Richter further states: "In the field of agriculture, of greatest importance is to account for cycles in production and to incorporate one's own cyclical production patterns to meet international market requirements". I think this misleading, especially with respect to trade in grains which is essentially generated by shifts in supply in importing and exporting countries. So far as I know, there is no respectable evidence of cycles in weather, which makes it doubtful whether formal modelling would ever be useful for predictive purposes, although this is not the only reason for modelling.

In sections III and IV of his paper Dr. Richter discusses the sorts of models that can be applied to agricultural trade and describes the methods adopted by FAO, OECD and the EEC. I do not wish to attempt to add much to this review of previous work, except to say that the traditional method adopted by FAO of predicting average production forward using technological information, and consumption forward from estimated income elasticities and

population assumptions, and then bringing the two elements together in a projection of price trends, leaves a great deal to be desired. It is arguable whether these are economic models at all.

"Gap analysis", as this approach has been called, ignores the self-correcting of imbalance by economic mechanisms. The trends revealed by such studies are likely to be reversed by adjustment to production, consumption and exchange rates that negate the forecast. Predictions, however carefully guarded their terms and even if they are presented as mere projections under stated assumption, frequently affect outcomes. I am not asserting that the only way predictions can be assessed is by comparing actual outcomes with predicted incomes: predictions or projections can be useful if they give market participants credible information in adjusting production and consumption.

However, official forecasts have occasionally brought about a convergence of expectations with uncritical acceptance of the authority of economists working in international agencies. Time is lacking to quote examples from recent history but official forecasting sometimes has made the situation worse rather than better.

One safeguard that would improve this situation would be for international agencies to observe standard academic conventions in reporting their empirical work. This has not been done on all occasions. It means their work cannot be evaluated properly by outsiders.

Dr. Richter concludes on an optimistic note. He refers to the "gradual abolition of trade restrictive practices allowing comparative advantage to affect allocation of production to economic criteria." I only wish I could share this hope.

## DISCUSSION OPENING – G. L. Johnson, *U.S.A.*

I find Professor Scheper's written paper and verbal comments very helpful. In my view, his paper correctly stresses the significance of the advances now taking place in modelling approaches and techniques.

In surveying international commodity, global, and what he calls transmission models, Professor Scheper concentrates mainly on what I call subject-matter and disciplinary, as contrasted to problem-solving, models. Some of the subject-matter and disciplinary models reviewed are of questionable relevancy; at least the *set of problems* and the *decision-making* units facing them are not specified by the researchers involved. For instance, Professor Scheper points out vis-a-vis global models that they "would be much more useful for a centralized world government." Important as it is to be able to relate models to problems and decision-making units, it is also important to note that problem-solving, global models are virtually impossible because their makers cannot obtain information by interacting iteratively (Dr. Petit would say adaptively) with global decision-makers. Thus, the informal components involving administrators (referred to as essential by both Dr. Petit and myself earlier in the Conference) cannot be established in developing global problem-solving models.

Inability to construct global problem-solving models for a non-existent world government does not preclude, however, the development of relevant global subject-matter and disciplinary models. Such models can be germane to sets of problems faced by well-identified, existing national and supranational decision-makers, both public and private, as discussed by Michael Tracy and Guiseppe Barbero.

The Club of Rome models discussed by Professor Scheper are of questionable relevance and value either as problem-solving or subject-matter models, at least, in my view. The Meadow's model, among its other shortcomings, treats the world as homogeneous – like a cask of fermenting wine in which the yeast population "explodes" to either consume all available energy or to kill itself by polluting its own environment with alcohol. The Pestel–Mesarovic model does disaggregate the world into 10 separate wine casks. They attempt both to improve the world data base and to integrate the 10 regional models, but, according to Professor Scheper, have not yet succeeded. I believe the data and linkage problems they face are surmountable for their models, as presently formulated. However, I believe that, to be usable, such models must be made stochastic with respect to the impacts of weather, at least, so as to permit Monte Carlo simulations through time to determine variances in the consequences resulting from alternative national and supranational policies. We need to know more about the variances in regard to who is hurt and benefited, how and in what way, where, and when? We also need to be able to study the relationship between equality, knowledge and control (through government), on the one hand, and global stability, on the other.

I do not know the Bariloche model but Professor Scheper's description of it indicates that it is more specialized on economics than the other two efforts. It seems to lack the technological dimensions of the Meadows and Pestel–Mesarovic efforts and to share their lack of attention to the political and military realities of the world. A recent issue of Harper's magazine* castigated the Club of Rome and the Pestel–Mesarovic model, in a conservative way, for political naivete and for lack of objectivity in dealing with normative and prescriptive knowledge.

The Linnemann model is also incomplete. The tentative conclusion presented to us by Dr. Scheper suggests thet the Linneman group may have incorporated constraints into their models to reflect some reality with response to the ownership of market, political and military power in the world scene.

The LINK project discussed by Professor Scheper is not familiar to me though it is in charge of L. Klein with whom I have collaborated in doing past econometric research. What is envisioned by Klein is the linking of national econometric models into global models. It is the same linkage problem which bothers the Pestel–Mesarovic team but then their more complicated models deal with technology as well as economics. Klein's linkage problems are likely

* Florman, Samuel C., "Another Utopia Gone", *Harper's*, Harper's Magazine Co., New York, New York, August 1976.

to be fairly easily handled compared to those of Pestel–Mesarovic. Methods can be used which are roughly similar to those used when we combine enterprise components into firm models and subsector components into sector models. Klein's linkage problems would multiply geometrically for stochastic models not specialized on economics and dealing with technological, institutional and human change while giving attention to the reality of existing and changing world-wide distributions of market, political and military power. Until we learn to build some of these elements into our global models, even subject-matter global models will be of questionable relevance.

Professor Scheper's discussion of the LINK approach for the agricultural sector is interesting and sensible. Linkage is essential but so are good model components to be linked. I feel that good relevant model components for linkage would accumulate more rapidly if we modelled:

(a) the multidisciplinary domains of practical problems before real world decision-makers. We should do this in a philosophically flexible way without specialization on techniques or disciplines. As many decisions of national and supranational agencies are executed in the world arena, this would help us develop relevant components for global subject-matter models;
(b) subject-matter areas such as food and nutrition, employment generation, energy in agriculture, trade, technology adoption, national agricultural accounts models, environmental impacts, etc. This should be done in a multidisciplinary, philosophically flexible way, unspecialized on techniques. Much is to be gained in doing this work from defining the sets of practical problems and specifying the corresponding decision-makers for which a subject-matter model is relevant;
(c) disciplinary (economic) aspects of the domains of practical problems. We do much good and relevant work of this nature. The results are valuable components of both subject- and problem-solving models. One thing for us to be careful about in doing such work is not to oversell it. After all it is specialized on economics in a world of dynamic technology, institutions and people. We seldom solve problems as economists alone. We do not sell out to government or become hostages to it when we recognize that we have not handled the political, military and other dimensions of a practical problem; instead, we win credibility for recognizing our limitations while doing that which we do best – economics.

Before closing, I would like to return to Professor Scheper's excellent paper and ask him if he would be in position to comment for us briefly on such national models as Heady's Thailand model, Leroy Quance's NIRAP model in the United States Department of Agriculture, the IBRD Mexican model as an example of a GSSSA model such as Halter's Venezuelan model or the Nigerian simulation model. The Nigerian model accounted for key projections of 62 out of 536 pages of the Nigerian government's document on "Agricultural Development, 1973–1985". I know Dr. Scheper was pressed for space and time in his paper and presentation and feel therefore that he might appreciate an opportunity to extend his review beyond the surplus/deficit, equilibrium and trade models he touched on in the first part of his paper. All

but one of the models I have just mentioned are complete or in advanced stages.

In closing, just a word about my optimism concerning models – and the GSSSA approach. My optimum is so realistic with respect to difficulties that it is hard to distinguish it from the pessimism of an equally realistic pessimist. Perhaps, my following discussant will be a realistic pessimist.

## DISCUSSION OPENING – M. Daad, *U.K.*

Let me say at the outset that I was glad Professor Scheper noted that "the influence of published models on decision in agricultural policy is still rather low". I agree that this is a correct appraisal of the situation up to now, although one should also note that some of the earlier models, particularly Limits to Growth, have provided a useful contribution to public awareness and to public debate about finite resources and the balance of food production and world population. I would say we are still in a preliminary stage of theoretical development of world models.

I outline briefly four reasons why I believe these models have had only a limited direct impact on agricultural policy so far.

(a) The aggregation of the models working so far has been at much too high a level. For example, in spite of a tendency to disaggregate countries in more recent models into a number of geo-political economic groups, it still remains very difficult for individual countries to assess the optional course of action open to them. Indeed, even if the EEC were to be considered as one such group, individual EEC member states would still wish to be able to analyse the implications of the estimated results themselves. There is also a problem of the level of aggregation of agricultural commodities. I would suggest that most of the policy decision on which government economists advise relate to priorities within the agricultural sector; for example, the relative emphasis which should be placed on arable and livestock, between feed grains and food grains, between feed based and forage based livestock systems. Certainly for these sorts of decision one needs information about the quantities involved and, most importantly, about the relative prices of agricultural commodities in the future. This has certainly been our experience in the assessments for the U.K. policy document "Food from our own resources". The problems of allocation of resources between, say, agriculture and the rest of the economy are arguably not addressed so often by policy-makers and are, in any case, very much more difficult to assess quantitatively.

(b) I would like to raise a related problem about the modelling of the main institutional structures into world models. I am particularly thinking of trade arrangements which can, of course, feed back into production patterns. Reference to milk products and sugar readily illustrates the relatively high proportion of world trade which can be covered by trading agreements. Clearly, for the model to give useful results for policy purposes these institutional arrangements need to be considered.

(c) The next reason why I would suggest agricultural policy-makers and their economic advisers have not yet been generally convinced of the usefulness of results of these models, is that the models have not been sufficiently validated. Professor Scheper has perhaps not given enough attention in his necessarily brief paper to the problems of validation of these large models. Certainly, the fact that most of these models are iterative, projecting the outcome of $t + 1$ on the basis of the outcome of $t = 0$ gives serious reason to reflect upon the possible confidence limits at $t + 10$ or $t + 20$. Perhaps I can illustrate the problem of validation with reference to the Pestel–Mesarovic model. The central structure of the inter-relationships is so complex that few, if any, apart from the modelling team themselves have successfully unravelled it. No-one has, to my knowledge, repeated the Mesarovic modelling runs to check the results. This is clearly a highly undesirable state of affairs, because it seems that for the time being at least, we have to take these results on trust. Policy-makers are, for the most part, quite reasonably not prepared to do this.

(d) There is the problem of the relationship of the policy-decision-maker to the model. I believe, one of the main criticisms of the Forrester World II model, and some of the other early models, is that it assumes a total lack of anticipation by the decision-makers who are implicitly contained within the model structure. All decisions within the World II model are based on the current values of variables. There is no possibility of decision-makers modifying their decisions to take into account the likely consequences of current course of action. Policy-makers, I would suggest, do not act like lemmings marching to the edge of the cliff and falling off, even though, in our more cynical moments, we might feel that they have to look over the edge first before turning back. Certainly the Systems Analysis Research Unit Model currently being developed by a U.K. government team, with which I should add I am not associated, like the Linnemann model, programmes the decision-maker as a rational being guided by self-interest. The alternative open to policy-makers also raises important and difficult questions about the appropriate treatment of R and D in models, particularly whether it should be treated exogenously or endogenously.

Finally, I should like to raise the question of the future place of these models in the national and international decision-making process. We have already heard a number of speakers at this conference express doubts as to the usefulness of mathematical models in agricultural decision-making. For my part, I believe that it is still too early to tell how useful these models might be, and that in the meantime we should continue to give support to this area, provided that the models remain simple and problem orientated. Professor Scheper says in his paper "The construction of global world models and link models will be one of the fastest growing disciplines in economics". If this is the case, and I am not in a position to question his judgement, I wonder whether he would indicate whether he believes this is an optimal allocation of our own scarce professional resources.

*Report of the general discussion*

Part of the discussion consisted of contributions on more or less factual matters. In respect of Dr. Richter's remarks about FAO activities in the modelling field it was stated that FAO's main purpose in the Indicative World Plan was to build up a *normative* framework for the development of world agriculture for a period of about 25 years, not a trade equilibrium model. Within this, the emphasis was on the feasibility of expanding agriculture in the LDC's consistently *inter-alia*, with their macro-economic goals and their nutritional needs. It was also stated that, contrary to the statement in the paper, the supply figures were not simply based on trends but stemmed from a determination for each developing country of a feasible development path and strategy, taking account of the physical and economic potential, and technological improvements. Discrepancies between the supply figures in the IWP and experience are of the nature of divergences between IWP guidance and government action. Turning to recent FAO activities the speaker said that the new Perspective Study of World Agricultural Development which FAO was just starting would try to improve on the IWP, for example, by developing supply figures by agro-ecological zones and by more integral handling of the nutrition and trade/self-sufficiency objectives.

As regards results from FAO's work in these fields, it was argued that, in addition to the activities of the various inter-Governmental Commodity groups, decisions at the World Food Conference indicated the usefulness of the IWP analyses – for example, those in connection with International Undertaking on World Food Security; the work on the International Fund for Agricultural Development, the International Adjustment Strategy, minimum aid targets and developments generally on World Food Strategy.

One or two speakers regretted various omissions or underemphasis on matters which they saw as essential elements in decision-making at international level. These included treatment of the role of trade in development, the implied perpetuation of the pre-existing international division of labour, a framework for analysing appropriate commercial policies for backward countries, consideration of DC's trade policies towards LDC's, the farm sector policies of advanced countries, international price stabilisation schemes and UNCTAD's successes and failures.

Professor Richter was pressed on his definition of comparative advantage in view of the results of research in several countries, for example, by Hayami and Ruttan, Evenson, and Valentini, suggesting that land might not be the fundamental element in it but rather investment in adaptive research and rural education.

In so far as the need for data can be divorced from the models and regarded as factual, Professor Scheper's implication that model simulations were limited by the difficulty of giving long-run estimates of exogenous variables was challenged on the basis that the majority of the variables in the models being discussed were endogenous. Though there was emphasis on the need for more data on the endogenous variables to anticipate seasonal fluctuations, the force of the comments on the lack of data seemed to relate to the uncertainties in

forecasts arising from lack of data on exogenous variables. In this connection doubt was expressed whether institutional and political variables could be omitted.

On the theoretical side the need for a fully valid foundation theory if extrapolations were not to lead to models at variance with facts, underlay various contributions, sometimes associated with grave doubts whether such foundation was available.

The positive types of model were seen by one speaker as inspired by the approach of natural scientists but to be consistent they must fulfil three conditions (i) the system must be closed, (ii) there must be complete knowledge of the state of the system and the relations within it and (iii) the law of conservation – but these are not met. (For example, see Northrop *The Logic of the Sciences and Humanities*.) So, in the speaker's view, there is no basis for reliable predictions.

Professional interest tended to press in the direction of greater research on international trade generally and more sophisticated models and interlinked complexes of models of individual commodities or subsectors. There were, however, voices arguing for more pragmatic analysis – it was reported that OECD had been working on an analysis of world food prospects which was not a projection exercise but gave a very useful guide to probable developments. It is, after all, important not only to know something of the trend but also of factors making for departure from the trend.

Though not expressing any doubts about the usefulness of "orthodox" model-building, some feeling was voiced – for example, in connection with the Meadows–Forrester approach – that a mystique was implied whereas in fact we were dealing simply with a useful tool which anyone could learn to handle in a few weeks.

Professor Scheper's support for the Day–Heidhues–de Haen type models for international linkage were criticised on the grounds that they often needed the introduction of rather *ad-hoc* flexibility constraints. The Duloy–Norton type of agricultural sector model was urged instead, since it explicitly includes price responsive primary factor supply and product demand relations. The model then simulates a competitive equilibrium, determining all factor and product prices endogenously, subject to policy and institutional constraints. It was stated that models were already being developed by the World Bank and others for a number of countries – for example, Mexico and the Philippines. They are open economy models and should lend themselves to the kind of linkages Professor Scheper suggests.

In response to Professor Scheper's pressure for more linkage of agricultural with non-agricultural sector models the PROLOG prototype modelling framework developed by Roger Norton *et al* at the World Bank Development Research was presented as an attempt at general equilibrium modelling in which interactions of agricultural and other sectors are explicitly included. There was the possibility that there would soon be enough price endogenous national agricultural models worked out to make it possible to begin on the linkage work which Professor Scheper had suggested.

Participants in the discussion included: A. Abdullah, *Bangladesh*; J. P. Bhattacharjee, *FAO*; J. Dubois, *France*; S. Midenberg, *France*; H. van Miltenburg, *Netherlands*; P. C. van den Noort, *Netherlands*; K. Prasad, *India*; R. Thomson, *U.S.A.*; M. Tracy, *EEC Belgium*.

J. J. Richter (in reply)

The complexity of international trade is such that it forces the researcher to single out items which he can safely investigate, document and present to a meeting like this. It was very helpful to have, from one of our friends, a catalogue of questions concerned with international trade problems.

Regarding the usefulness of models, I do not feel that I have to justify the plain fact that economic theorising has its own merit and justification, but the quantification methods we use in agricultural economics have to be applied so that we receive, at least in some degree, explanatory as well as predictive or indicative answers to the questions we pose. I was very careful in the paper to say that, so applied, these models are an aid to the decision-making process, contributing to the intelligence with which we handle international trade problems. Models are not substitutes for policy-decisions but they can be, if wisely prepared, an aid to the decision-making processes.

We are so very reluctant to accept that outside the economic fields there are decision-making processes which affect agricultural economics in spite of the fact that they are so incredibly difficult to quantify. In regard to international relationships, I find very often that it would be helpful if we borrowed from our colleagues in the other social sciences and political sciences. We have basically utilized only "switch on, switch off" dummy variable systems without taking advantage of the very advanced knowledge of social scientists in other disciplines.

I agree that the question of exchange rates in agricultural trade is of the greatest importance. I singled them out in my original draft, but came to the conclusion that they were too complex a problem to be handled in the paper. In relation to our experience, I would only point out that the European Economic Commission has been working in this field for many years. The Commission is seeking better solutions, but to date we must use the tools available. A very similar situation applies to the COMECON. Originally, international or regional trade in the COMECON was based on fixed prices, but they learned by experience that adjustments over time were needed. I certainly want to give credit to our friends in the East for developing serviceable models in this field. I personally do not believe that the predictive truths we have developed are worse than the previous ones and therefore I think that some contribution to this can be derived from models.

W. Scheper (in reply)

As I mentioned in my paper, it is very hard to solve the data problem for models of the Meadows type. A discussant argued against it and said that the

important variables of the Meadows Models are indigenous and calculated from year to year. That is correct. However, there are many parameters which have to be estimated exogenously and I tried to say that it is very difficult to forecast the values of these parameters. I agree that it is a weakness of my paper to neglect national agricultural models of the World Bank Mexico type. These models are indeed a good starting point for international linkage approaches. I am in line with Professor Johnson's argument that model-builders should put more emphasis on possible variations of parameters in future and the consequences which arise from these variations. Dr. Daad pointed out that the interpretation of models is very important. To have an influence on agricultural policy, economists must present results and assumptions of their models in a way which politicians can understand and, furthermore, in a way which provides a foundation on which the politician can base trust in the economist.

I felt that Dr. Daad's argument is one of the most important arguments in this session. Useful world models will be very complex and, therefore, necessarily there will arise the Black Box problem. This means that the model-builder cannot explain everything in very simple terms and, therefore, the politician has to trust the economist to a certain extent. The construction of complex models certainly takes a long time. They are never ready – in the sense that no further improvement and adjustment is possible. Further improvements and adjustments of existing models very often seems more useful than starting with a very different new model.

Finally, in my opinion the discussion gave too little attention to link problems. I feel that in the coming years we should invest a lot of work to link agricultural models with highly integrated macroeconomic national and international models.