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A SIMPLE MODEL OF CHINESE AGRICULTURE

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April 1985
WP-85-18

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FOREWORD

Understanding the nature and dimensions of the world food problem and the policies available to alleviate it has been the focal point of the IIASA Food and Agriculture Program since it began in 1977.

National food systems are highly interdependent, and yet the major policy options exist at the national level. Therefore, to explore these options, it is necessary both to develop policy models for national economies and to link them together by trade and capital transfers. Over the years FAP with the help of a network of collaborating institutions has developed and linked national policy models of twenty countries, which together account for nearly 80 per cent of important agricultural attributes such as area, production, population, exports, imports and so on. The remaining countries represented by 14 somewhat simpler models of groups of countries.

Since China is a large country, we had to include a model of its agriculture in our system. The limitations of available statistics, however, made it difficult to develop a detailed policy model for China. We have, therefore, built a simple notional model of China in order to represent in a reasonable way China's effect on the international market. Even though the model is somewhat simple in its conception, it does help in making our scenarios for China's agricultural development internally consistant and our assumptions explicit. Marta Neunteufel has described such a model in this paper.

This working paper is one of a series of working papers documenting the various national models developed by FAP or by members of its collaborating network.

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ABSTRACT

A simple model of Chinese economy is developed which is compatible with IIASA FAP Basic Linked System. The purpose of the model is to provide a tool to generate internally consistant scenarios of China's agricultural development and trade patterns.

On the basis of a very simple model covering the entire Chinese economy, alternative scenarios of foreign trade of ten commodities (nine agricultural and tenth being the "nonagricultural commodity") are generated up to 1990.

The model consists of five blocks: an exogenous population block; a government block, where some policy variables can be set; a production, and exchange and an accounting block. The most elaborate block is that for production, describing the development of the main productive factors of Chinese agriculture. The exchange block creates the bridge between domestic production, consumption and world markets.

Both production and consumption of the commodities considered are dealt with. Export of a commodity results from production surplus over consumption requirements; import requirements stem from higher consumption requirements than can be covered by domestic production. The balance of payments is handled as a limiting factor. Nutritional standards are computed as well.

Several simulation runs have been carried out, most of them describing some variants and follow-ups of alternative Chinese political measures, and using some plan-numbers. The model work was completed in December 1982.

ACKNOWLEDGEMENTS

I would like to thank Klaus Frohberg, Kirit Parikh, Ferenc Rabar, and F.C. Tuan, who provided helpful remarks and suggestions, Ms. Bozena Lopuch for the computational work and Bonnie Riley and Cynthia Enzlberger for the text processing.

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A SIMPLE MODEL OF CHINESE AGRICULTURE

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1. INTRODUCTION AND BACKGROUND INFORMATION

1.1. Modeling Purpose

The model system being built at FAP aims at covering the globe with specific national models of major countries comprising about 80 percent of the world's population, agricultural production, land base and foreign trade of agricultural products. China, with 22 percent of the world's population and accounting for 13 percent of the world's agricultural production, has to be included even though adequate data are not available.

As a first step, a problem assessment was prepared (see Neunteufel, 1979). Now a simple model of Chinese agriculture will follow. The model is simplified in two senses: it is based on the 10-commodity aggregation as used in the national models of the FAP basic linked system, and it describes the main components of Chinese agricultural development in a simplified way.

The purpose of the model is to provide a tool to generate internally consistant scenarios of China's agricultural development and trade patterns. We will attempt to answer questions such as: How much grain can and must be imported in order to supply enough food at a given level of production and at balanced foreign trade? How can a balanced foreign trade be sustained for a longer period and consumption and investment requirements met at the same time? It is important to stress that the model and its results are of hypothetical nature, and that the model is not a forecasting tool.

Much has been written about the functioning and special problems of China's agriculture and its whole economy, but the statistical data base is, in spite of the considerable amount of data recently published, still not adequate. As the low population estimate from John Aird (1978) from USDC lies closest to the official population figures, this is used in the standard-setting of the model. This includes the implicit assumption that birth control programs would succeed in the future.

In the light of the poor data availability an attempt was made to construct such a simple but consistent description of Chinese agriculture that the model should show how the requirements of supplying enough food for the population, need of investing now to be able to produce enough tomorrow, and keeping foreign trade balanced (or at a given level of deficit), influence each other.

Before turning to the model, a short description of present Chinese agricultural development should enlighten the basic problems.

1.2. Chinese Agricultural Development 1977-1981

1.2.1. Policies

Since the early 60s Chinese official policies stress the basic importance of agricultural production and especially grain production. Slogans such as: "agriculture first", "agriculture is the foundation of the national economy, food grains are the foundation of the foundation" have been widely used. In practice, however, no major changes have been introduced until 1977. The policy reform started at that time is expected to continue for a longer time, being a cautious modification procedure of earlier policies.*

Before discussing the policy changes after 1977 in detail, two questions should be answered. Why have policy changes become an urgent necessity in 1977, and how far do policies affect agricultural production in China?

According to a study by A.M. Tang† Chinese output growth has been a very high-cost growth. He claims that aggregate input index of agriculture has grown 260% during the period 1952-1980, while the index of gross output has grown only 237% during the same period. For the development of value added per worker he computed a 26% decrease between 1958 and 1978. Although Tang's method was criticized** among others also by Lardy, he also stresses that ill-advised planning methods have depressed the growth and efficiency of agricultural production, but perhaps less than computed by Tang.

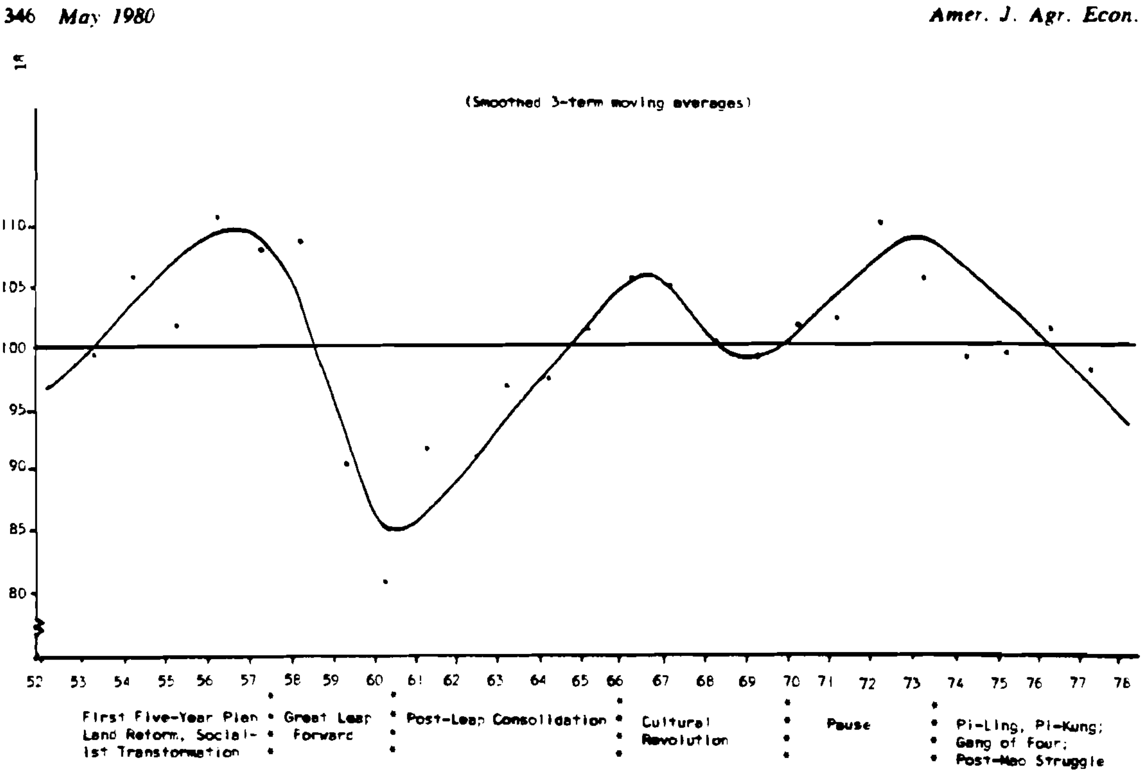
According to a report of the Institute of Agricultural Economics of the Chinese Academy of Social Sciences‡ grain yields have increased in the production units they investigated at an average annual rate of 2.8%, while costs have increased 4.0% a year during 1965 and 1976. This study gives the decline of the value of a labor day from 0.70 yuan to 0.56 yuan for the period above.

Whatever the exact level of declining productivity is, it is obvious, that in spite of enormous efforts made, agricultural production just could keep on with population growth until 1977, and consumption levels could be increased only marginally. Agricultural policies applied are greatly responsible for that.

This is insofar important, as Chinese agricultural production is highly responsive to political changes. A.M. Tang* who investigated the development of total agricultural production, was able to show that there is a very close relationship between agricultural production and policy cycles. He assumed that the agricultural output in any given year is determined by a) the inputs utilized and the technology applied, b) the economic milieu and c) weather. Eliminating the effects of the trend-component described in a) and the disturbance term described in c), he separated the cyclical component of the time series. This cyclical component corresponds exactly to the historical policy cycles of the period under investigation.

* see e.g. Dernberger (1980).
† Tang (1980, IFPRI) and Tang (1982).
** See Lardy, 1980.
‡ cited in Dernberger (1980)
*A.M. Tang: Trend, Policy Cycle and Weather Disturbance in Chinese Agriculture, 1952-1978. Am.J. of Agric. Econ. May, 1980.

Figure 1. The cyclical component of Chinese agricultural production, as computed by Tang.



As the figure very impressively shows, total factor productivity index was sharply falling between 1973 and 1977. With stabilizing the political situation and starting the new reform course, agricultural production increased sharply in the next years. In addition, 1979 weather conditions were very much favorable, so China reached the highest agricultural output of her history.

Table 1. Production and yield of some agricultural commodities 1976-1980*

Production million m.t.	1976	1977	1978	1979	1980
wheat	50.5	41.0	54.0	62.7	54.2
rice	126.0	128.5	137.0	143.7	139.3
coarse gains	70.5	70.7	79.2	83.0	82.5
cotton	2.050	2.049	2.167	2.207	2.707
soybeans	6.60	7.30	7.60	7.46	7.88
Yields m.t./ha					
wheat	1.78	1.46	1.85	2.13	1.88
rice	3.48	3.61	3.98	4.25	4.17
coarse grain	2.07	2.09	2.36	2.51	2.52
cotton	0.414	0.423	0.447	0.490	0.564
soybeans	0.985	1.074	1.070	1.036	1.079

*Source: Agricultural Situation: People's Republic of China Review of 1980 and Outlook for 1981. USDA ESS, Supplement 6 to WAS-24.

These production increases are highly determined by increased use of several agricultural input factors (mainly fertilizer), but at the same time are resulted by the changed policies.

By "putting economy in command", i) the role of material incentives has increased, price mechanism received greater emphasis, ii) at the same time, planning and control started to undergo a decentralization process, iii) marketing mechanization of agriculture is going to be improved as well.

i) The average quota procurement prices for the major agricultural products have been increased by 20-50% in 1979. In addition, procurement price of cotton has been increased in 1980 again.* These have resulted in - especially strikingly at cotton - sharp increases in the production. But not only price incentives were very effective: bonus fertilizer deliveries and additionally distributed private plots to produce feed grains enabled sharp increases in yields and in meat production, respectively. The role of private plots has become more important than ever in the last decades; land area of private plots has tripled, now it is 15% of farmland. 17.1% of total value added of agricultural output was accounted for this sector in 1979.** Due to improved marketing possibilities of products from the private plots, 26% of rural households' income stems from this source.

ii) Decentralization of planning, and making teams the basic decision units, enabled an efficient use of the possibilities given by the material incentive. The elimination of acreage quotas for grain crops, and the guarantee of greater grain deliveries for areas which specialize in cash crop production, resulted in better diversification of production. Using comparative advantages of suitability of different land classes to produce different crops, this specialization might have played a great role in yield increases. Although decentralized planning and reduced direct control had favorable effects in diversification and specialization, undesired side-effects have occurred as well, e.g., total grain area decreased by 1.7% between 1978 and 1980, and there is serious concern about how far this process should be allowed to continue.

iii) Increased incomes (the per capita income distributed by communes was 140% in 1979 compared to 1970†) increased demand (with the only exception of meat, procurement price increases, have not been passed to consumers) and the regional specialization call for better marketing organization. Commercialization rates of different crops are highly varying: while 98% of cotton production is sold to the State Purchasing Organizations, only 20% of grain production reaches this channel.‡ If regional specialization should be sustained also in the future, grain commercialization level has clearly to be increased. Improvement of food supply for both urban and rural population, supply of consumption commodities and agricultural inputs will depend very much on development of the marketing mechanism. This, in turn, requires not only organizational and institutional changes, but also high investment in infrastructure, transportation, etc.

The development of policy changes in China depends in my opinion on three basic decisions, namely a) how far increased income inequity will be tolerated when striving at efficiency, b) how far self-sufficiency of regions and of China as a whole will be stressed with respect to special crops and c) how far foreign trade can be balanced, or if this will be required at all.

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*F.M. Surls and F.C. Tuan: China's Agriculture in the Eighties, USDA ERS, August 1981.

** SSB

† SSB

‡ Surls and Tuan op. cit.

a) Efficiency versus equity. It is obvious that in such a huge country like China economic development has been traditionally uneven, great regional inequities have existed. Agricultural production (and hence income of rural population) has been always depending on the natural conditions. But also industrial development has been concentrated on some favorable (e.g. coastal) areas. These traditional inequities could not have been overcome by the Chinese regime, perhaps not even alleviated.

Several attempts were made in some periods in the history of the People's Republic to eliminate the second level of inequities - within a region, within a commune. But egalitarian distributing principles within one production unit (commune, brigade, team) have led to economic inefficiency.

Now, with regional specialization, and less direct control, regional inequalities might increase, unless poor areas receive support from the state to develop their best possible production sectors. The question is, how far such a reallocation of resources can take place to achieve a generally optimal efficiency, how far the more developed regions will be willing to support backward areas, or how far this will be forced at all.

The second level of income inequalities depends very much on how much production teams will be independent, how much production on private plots will be encouraged. As the commune system is going to be sustained, this might give some immanent limit to income differences within on unit. Still, these income differences might become undesirably high from the political point of view.

b) Self-sufficiency of regions was an often-stressed principle in the PRC. Regions, not very much suited to produce grain, for instance, were forced to do so - which sometimes meant high losses in efficiency. Although self-sufficient regions had great importance from the strategical point of view, there have been practical reasons to push self-sufficiency as well. Inadequate infrastructure and transport systems simply force development in this direction. Again, the question is if the resources for investments will be sufficient to build up the required infrastructure. And, last but not least, how far the strategical importance of self-sufficient units will be evaluated against economic efficiency.

Self-sufficiency for China as a whole with respect to special crops will most probably remain a guiding principle.

Although Chinese grain imports have rapidly increased in the past 5 years, the volume of grain imported has not been more than four percent of total grain production. It is generally expected that grain imports will not increase in the future and will range between 12 and 16 million tons a year. At this size of grain imports China would not be dependent on world grain markets, as many of the developing countries are. Parallelly, production of cash crops is forced as well - import requirements of soybeans, cotton, sugar are going to be eliminated.

So we can conclude that as long as the call for regional self-sufficiency might be stopped, self-sufficiency in the agricultural commodities for the country as a whole will be stressed in the future as well.

c) But China wants to be self-sufficient not only in her agriculture. Foreign trade has been kept balanced in recent years: agricultural imports have been balanced by nonagricultural exports and vice versa. As agricultural production has been boosted since 1977, and this is going to be continued, agricultural imports can be limited also in the future. As Chinese have traditionally avoided high foreign debts (this has been continued also after entering the IMF and the World Bank), fast development of agriculture should enable to keep foreign trade balanced, as nonagricultural import requirements (modern technology!) are still high.

Table 2: China's Foreign Trade Figures

Item	1976	1977	1978	1979	1980	1981[1]
Million[2]						
Total exports	7,268	8,101	10,118	13,751	19,493	22,400
Farm export[1]	2,680	2,648	3,118	3,629	4,324	4,900
Total imports	6,023	6,615	10,351	14,383	19,316	18,600
Farm import[1]	950	1.918	2,475	3,364	5,359	5,300
Trade balance						
All products	1,245	1,486	-233	-632	-177	3,800
Farm products	1,720	730	643	265	1,032	-400

[1]Preliminary
[2]All values given for China's trade are f.o.b.
Source: Foreign Agriculture; The China Trade. USDA Foreign Agricultural Service, August 1982.

1.2.2. Development of the main agricultural input factors

1.2.2.1. Land

China is an extremely land-scarce country, only 10.4% of her total area (i.e. 100 mill. ha) was cultivated in 1975.* This is less than in 1958, when the State Statistical Bureau** reported the figure of 107.8 mill. ha. Since 1975 the cultivated area has declined again, according to the SSB report of 1980 it was only 99.61 mill. ha in 1979. As the index of multiple cropping has not increased very much according to the official statistics (it was 145% in 1958 and 149% in 1979), the total sown area has increased from 145.3 mill. ha in 1958 to 148.4 mill. ha in 1979.

According to a study made by the Geography Institute of the Chinese Academy of Sciences,† between 1950 and 1958 the area of cultivated land increased continuously year by year, reclamation of wasteland was encouraged throughout the country. Between 1958 and 1978 cultivated land decreased, in the average one million ha a year. This decline has resulted from withdrawal of 33 million ha from cultivation because of salinization, erosion or for other usages (industrial, housing, etc.); and a total reclamation of 21 million ha.‡ According to recent plans cultivated area should increase by 8 million ha until 1985. Since the reclamation of this area might be very costly, the target will most probably not be reached.

Increases of sown area by intensifying cropping will also be difficult, as multiple cropping was strongly forced in recent years, as much that in some cases it became already uneconomical. It is not likely that the multiple cropping index would increase substantially in the eighties.

* Source: China Report of Agriculture, No. 138, Foreign Broadcast Information Service, May 1981.
** Ten Great Years: Peking 1960, Foreign Language Press.
† China Report of FBIS, op. cit.
‡ F.M. Surls and F.C. Tuan op. cit.

It is worthwhile to mention that both cultivated area and multiple cropping index were overestimated by experts before official data were published. An IFPRI study in 1980§, for instance, estimated the cultivated area being constant between 1962 and 1977 at the level of 107 million ha. The index of multiple cropping was estimated to have increased from 136.1% to 157.9% during the same period. This means that according to this estimate total sown area reached 169 mill. ha in 1977, almost 20 million ha more than the official data.

Grazing land was estimated to be 37.1 % of total area in 1975.* As animal husbandry is going to be developed very fast in the next years, and especially ruminant-type of animal production is stressed (feed grain availability is being a constraint also in the future), improved usage of grazing land received high attention.

12.7% of land area in China is covered by forests. This is regarded as too low, and great efforts will be made to increase it. Because of its high ecological importance, afforested area should reach 20% of total at the end of the century.

1.2.2.2. Water

Irrigated area has reached 47.7 million ha in 1978, 48 % of total cultivated area.** This conforms with earlier experts' estimates (e.g. the IFPRI study cited before) and shows a remarkable growth, namely 13.3 million ha since 1957. With rapid increase of chemical fertilizer application and improvements of crop varieties, irrigation has been a significant factor in increasing yields. Irrigated area was mainly extended on the North China Plain, were rainfall doesn't provide adequately for crop growth. As tubewell irrigation was very intensively used on this area, some serious problems have arisen as well. The lowering of the water table calls for caution in further expansion. A more efficient usage of already existing irrigation facilities received greater emphasis.

No large increases of irrigated areas are expected. The regulation of the Yangtze River, being planned for a long time, will be necessary, but very expensive. Thus, at the time being, small-scale and low-cost improvements of already existing systems are stressed. Waterlogging, salinization and soil erosion due to improper water management systems should be stopped. In the next years these improvements would enable sufficient yield increases and large-scale projects could be postponed.

1.2.2.3. Fertilizers

Rapidly growing application of chemical fertilizer has been the main source of yield increments in the last decade: average chemical fertilizer application has doubled between 1970 and 1977, and again between 1977 and 1981. This is the result of the forced expansion of domestic large-scale fertilizer production. As 13 nitrogen fertilizer plants contracted at the early 1970s went into production at the end of the decade, fertilizer availability enabled the application of 127.8 kg (nutrient value) per ha in 1980.†

This very impressive growth of chemical fertilizer production (on the average 23% annually) will not continue, however. Although plans have been elaborated to build one large fertilizer plant per province until 1985, the

§ A.M. Tang and B. Stone: Food Production in the People's Republic of China. IFPRI Research Report No. 15, May 1980.

* China Report of FBIS, op. cit.

** Source: Agricultural Situation: People's Republic of China. Review of 1980 and Outlook for 1981 USDA ESS, supplement 6 to WAS-24.

† Agricultural Situation: PRC, USDA ESS op. cit.

procedure of planning and construction such plants has slow down. The more, small-scale, ineffective and poor-quality producing plants are going to be closed.

The emphasis has been pushed more to the quality side of application in contrast to the quantity expansion of the last years. Better care and storage, transportation, improvements at the proportion of different chemical fertilizers applied, improvements in distribution of fertilizer application among the crops within the multicropping system are stressed.

But the role of organic fertilizers has not decreased at all. They are still treated as the main fertilizer, while chemical fertilizers are considered as stimulating ones.*

Wide-scale collection of all organic fertilizer and careful treatment of them will keep busy a large part of Chinese rural labor force also in the future. According to the study of A.M. Tang** already 90% of animal and human manure is utilized in rural areas. Additionally, green manure, oil cake, compost and mud are applied. 73% of total nutrient weight of fertilizer came from this source in 1977.** Using Tang's method of calculation we get that in 1980 still over 65% of fertilizer nutrients applied can be accounted for organic sources.

As the utilization rate of organic fertilizer is already very high and its sources are limited, and, from the other side, rapid growth of chemical fertilizer production is not expected, fertilizer most probably will be a limiting factor to yield increments. China is expected to import much fertilizer also in the future. Both fertilizer production and imports will be forced to ensure a more balanced proportion of fertilizers applied (i.e. more phosphorus and potassium) than before.

1.2.2.4. **Mechanization**

The importance of agricultural mechanization has been often stressed in China, but the emphasis of this program was changed over time. As long as according to plans in the mid-50s basic mechanization of agriculture should have been completeed by 1980, plans elaborated in 1977 and 1978 called for 70 % basic mechanization for 1980 and 85% by 1985.

Mechanization is a complex problem in China since different producing regions require basically different forms of mechanization.

As long as in the Northern, Northeastern areas, where cropping seasons are short, fields are of large size, tractor ploughing, mechanized sowing, threshing, drying are of high importance. These areas are relatively sparsely populated, reclaimable areas are still available. Thus mechanization can serve to expand producing areas and increase production during the limited period of cropping and at the limited size of labor force available.

In the Southern and Southeastern areas, where multiple- and intercropping is widespread, mechanization has to have a very different character. Labor in these areas is abundant - labor-saving techniques are not desired at all, unless superfluous labor force can be absorbed by other production sectors. Here the main emphasis is to shorten periods between two crops, as even short delays in these times can result in high losses. In this sense application of rice-transplanters would be of highest importance.

But even the geographic conditions require different types of machines. In

*See e.g. the study already cited, FBIS China Report, May 1981.
**A.M. Tang and B. Stone, op. cit.

the North, large size tractors are applicable, in the South small-size hand-guided tractors are more effective.

The difficulties connected to the complexity of mechanization programs resulted in uneven development, historically and regionally as well. In spite of this, and the difficulties connected to production of agricultural machinery* (poor-quality steel, improper design, lack of spare parts, etc.) the development of mechanization is very impressive. Total horsepower of agricultural machinery has increased sixfold** between 1970 and 1979, and has reached at the end of the period 181.91 million hp, irrigation equipment has almost increased fourfold in the same period. Tractors come up for one-fourth of total agricultural machinery horsepower, and plough 42.4% of total cultivated area. Combine numbers have trebled, as well as dryer machines. Twice as much threshers were used in 1979 than in 1970.

The regional distribution of this machinery corresponds to the regional requirements, for instance the share of tractor-ploughed areas is higher in the North (57% of area)† than the national average.

As a result of fast mechanization, electricity used in rural areas has increased from 9.57 billion kW in 1970 to 23.27 billion kW in 1979.‡ and 40 % of diesel fuel is now consumed by farm machinery.

A slowdown of farm machinery production and sales in 1980 might be the result of changed mechanization policy; more complexity, selectivity and energy saving character will prevail.

1.2.2.5. Labor Force

Until 1980, when first official data were published, not very much was known about China's agricultural labor force.

The estimates of experts were widely divergent from each other, depending on which population estimate was used, which percentage of the population was estimated to live in rural areas, and which employment rate was assumed.

The official data*** on labor force are as follows:

Table 3. Distribution of labor force

Year	Labor force Total	agricultural	urban
1970	344.23	278.14	66.09
1975	381.61	294.60	87.01
1979	405.86	294.25	111.61

It is an important fact that growth rate of agricultural labor force has been continuously declining. As long as between 1960 and 1970 it was 3.5% annually, during the next five-year period it was practically zero and the share of agricultural labor force in the total has declined from 80.8% in 1970 to 72.5% in 1979. This means that the total growth of labor force has been absorbed by urban areas. This is connected to the less restrictive migration policy effective in this period, and has created some urban unemployment.

* See e.g. M. Neunteufel: Problem Assessment for China, IIASA WP-79-116, p. 20.
** 1data are taken from SSB 1980.
† F.M. Surls and F.C. Tuan, op. cit.
‡ 1data are taken from SSB 1980.
*** SSB 1980.

T. Rawski§ § who assumed that urban employment can increase between 5-7% annually, and gives the urban employment figure of 87.1 million for 1975 is very close to the official data. Using his assumption, the population age-structure given by J. Aird** and the correction term derived by F.W. Crook*** to get labor force from the age group of 14-64, we can compute the agricultural labor force for 1979 as 295.14 million, very close to the official data. This is important insofar as for estimation of agricultural labor force for future years, this seems to be a reliable method.

1.2.2.6. Agricultural Research

Agricultural research is, and will be, the most critical point of agricultural development in China. As a result of the Cultural Revolution, bases of solid research and education have been practically destroyed. As present Chinese leadership is conscious of the serious errors committed earlier and their consequences, great efforts are made to develop a modern research and education system.

The problem is not easy at all: although China has remarkable cooperation with several research institutes all over the world (e.g. the International Rice Research Institute), and Chinese scholars study modern technologies in the USA and Europe, the special character of China's agricultural system doesn't allow a simple adaptation of foreign technologies or foreign crop varieties (e.g. the first trial to adapt rice varieties from the IRRI was not successful). Thus only a more time and resource intensive progress can overcome the gap: the whole internal system of agricultural research, education and extension has to be developed. Resources are concentrated on key regional institutes and universities, each with its own area of specialization.†

As the earlier chapters of this study showed, increased application of physical input factors is constrained. Thus, yield and production increases are depending greatly on how improved varieties can be developed and extended, and how far more appropriate agricultural techniques can be introduced.

With respect to yields of some crops, fast increases are possible, mainly where Chinese yields are low by international standards (e.g. wheat, soybean). Perhaps even more importance has the proper choice of techniques. As the quality improvement of production is strongly stressed by present policies, and ecological problems also force in this direction (see e.g. problems of irrigation and mechanization), development in this field will be the most important and resource-consuming task for the next years.

1.2.3. Agricultural Production

The production structure of China's agriculture is clearly dominated by the crop production, as the following figures demonstrate.

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§ § T.G. Rawski: Economic Growth and Employment in China. Published for the World Bank, Oxford University Press, 1979.

**J. S. Aird: Population Growth in the People's Republic of China in US Journal of Economics, Chinese Economy Post-Mao, vol. 1., Washington, D.C., US Government Printing Office, 1978.

***F.W. Crook, the Commune System in the People's Republic of China, 1973-74, US Journal of Economics, 1975.

† F.M. Surls and F.C. Tuan, op. cit.

Table 4. Total value added by agricultural production* (100 mill. Y)

Prod. value	1978	1979
Crop production	988.57	1059.65
%	67.8	66.9
Forestry	44.43	44.99
%	3.0	2.8
Animal husbandry	192.97	221.19
%	13.2	14.0
Processing	212.50	238.92
%	14.6	15.1
Fishery	20.3	19.55
%	1.4	1.2
Total GVAO	1458.77	1584.30
%	100	100

* Source: SSB 1980.

Within the crop production grains play still a crucial role, as also shown by the cropping areas.

Table 5. Area sown to the main crops* (mill. ha)

Crop	1975	1976	1977	1978	1979
Grains**	121.62	120.74	120.40	120.59	119.26
Cotton	4.95	4.93	4.84	4.87	4.51
Oil crops	5.65	5.79	5.64	6.22	7.05
Sugar crops	0.83	0.90	0.86	0.88	0.84

** includes tubers and pulses.

As the figures shown in Table 1, grain production and grain yields have reached their highest value in 1979, and declined in 1980. This is due only partly to unfavorable weather conditions in 1980. Areas sown for grain have declined, as a result of policies encouraging cash crop production. As China most probably will not increase her grain imports, one can assume that the rapid decline of grain areas will be stopped, or high increments of yields will be strived for, even if this can imply high costs (in inputs, research, etc.). As the solid increase in grain consumption is going to be sustained and an increase of feed grain imports is not expected, it is an open question whether the fast increase of meat production of recent years can continue.

But if China is not willing to depend on the world market, and will not increase her grain imports, this means that still the grain problem is the basic one to solve. How to produce enough grain for food consumption, for a desirable growing meat production on a constrained area, to be able to produce cash crops at a higher level as before? The future of the whole Chinese agricultural production and of the development of food supply depends on how the task of an efficient grain production can be solved.

According to a study carried out at the Cornell University†, the grain sector will have a critical effect on the agricultural and economic development of China, and the basic problem is "not whether grain production can grow in the

† R. Barker, D.G. Sisler and B. Rosei: Prospects for Growth in Grain Production in University of Cornell International Agricultural Economics Study, A.E. Res. 82-9, March 1982.

future, but whether needed supplies can be obtained without slowing the rate of growth of the rest of the economy." The success will depend on how new technologies will be introduced and how agricultural infrastructure will be extended. Difficulties in scientific research and investment bottlenecks, discussed in earlier chapters of this paper, might become constraints in grain production in the near future.

Production of oilbearing crops have been uneven since 1975. Both areas and yields dropped in 1976 and 1977, but there were sharp increases in 1978 and 1979. Thus areas sown to oilbearing crops increased by 24.8% in 1979 compared to 1975, and yields by 14.0%. As a result production has grown by 42.2%* during the period. Still, oil supplies are going to be tight and China is expected to continue to import edible oils to be able to meet growing demand.

As a result of the policies forcing cotton production, yields have increased substantially, from 414 kg/ha in 1976 to 564 kg/ha in 1980,** and although cotton areas decreased by 3.1% during this period, production has reached 2.707 million tons in 1980, a remarkable growth of 32% over the production in 1976. This was a clear success of cotton production in the Northern areas, where cotton areas were extended in 1980 and yields increased by 82%. This enormous yield increase was enabled not only by using more fertilizer, but also be extended use of high-yielding varieties and by switching cotton production to more fertile fields. (One should not forget: procurement prices were increased for cotton by 15% in 1979 and by 10% in 1980!).

Still, due to rapidly increasing demand for cotton cloth, (rural and urban purchasing power increased 34% from 1978 to 1980 †) and the limited capacity of the synthetic fibers production, import demand is high.

Although areas used for sugar production has remained relatively stable in the last years, sugar production increased sharply (41.5% between 1977 and 1980) and reached the record value of 2.570 million tons in 1980.‡ As a response of the policies applied, areas devoted to sugar beet production increased by 45% in 1980. Although sugar cane area decreased by 3%, the yield increases (40% at sugar beet, and slight increases at sugar cane) enabled record production. As domestic demand is higher than production, China is forced to import sugar as well.

In recent years meat production was the most rapidly developing sector of Chinese agriculture: total output of meat (pork, beef and mutton) has increased by 15.6%* at the average between 1977 and 1980, and reached 12.055 million mt in 1980.

The main bulk of Chinese meat production (94% in 1980) is pork. Hog inventory steadily increased until 1979 (the average growth rate was 2.71% between 1975 and 1979)† The year end stock number of hogs was 319.71 million in 1979, but it decreased to 305.43 million for 1980. The reasons for this development are the following ones.

Promoting meat consumption, procurement prices were increased in 1979. Additionally, as already mentioned in this paper, feed supply was improved (e.g. by additional private plots for feed grains). As a result, inventory numbers went up by 6.1% in 1979, but due to higher sales and increased slaughtering rate went back by 4.5% in 1980. Still, efficiency of pork production is slow, both

*Source: SSB 1980.
**Source: USDA.
† Source: USDA CES.
‡ Source: SSB

slaughtering rate and carcass weight of animals is low compared to international standards. Accordingly, policies have slightly changed in 1980, instead of stressing the importance of quantities, the quality of breeding and rapid turnover is emphasized. Although good harvests in 1978 and 1979 enabled sufficient feed supply, feed might become the limiting factor in the future. Production of forage crops is forced, as there come up for a great part of feed requirement and a less extensive development of pork production is strived at.

At the same time, breeding of ruminant type animals is forced as well. This would enable improvements of living standards in pastoral areas, increases of milk production (which is very low at present) while it requires less feed grains compared to hog breeding. Increased stock of grazing animals will call for better management of grazing lands.

Production of poultry and rabbits is increasing as well.

As a result, supply of meat, milk and eggs could be improved, and exports could be sustained as well.

At last, one should mention that China's agricultural production is dominated by the communes, the overwhelming part of total value added is produced by the collective sector, while importance of private sector is growing.

Table 6. Total value added of agricultural production
by sector of ownership*

Sector	1978	1979
State farms	3.5%	3.7%
Collective sector (Communes)	80.5%	79.2%
Families (Private)	16%	17.1%

1.2.4. Food Consumption

Table 7. Food ratios in 1979 (kg/year/person)*

grain**	
national average	342
rural population	408
edible oils	2.504
sugar	2.505
meat	10.95

* Source SSB 1980.

** PRC definition, includes pulses and tubers as well.

As data show, food ratios in China (especially oil, sugar and meat) are still low, however with the addition of nonrationed foodstuffs (fruits, vegetables, etc.) an adequate average food consumption level is sustained.

The grain figures shown in Table 7 are quite high, but one should not forget that they are given according to the usual Chinese definition, i.e. they include pulses and tubers as well. Furthermore, in rural areas grains for feeding purposes are included as well.

A very crude estimate of human grain consumption for 1980 (not including pulses and tubers) would lie between 225 and 240 kg per caput.* This means that roughly 80% of total calorie intake of Chinese people is supplied by grain calories. However, this is a very approximate figure, and great differences might exist. Grain consumption is higher in rural areas, while due to higher incomes in urban areas people consume less grain and more meat. But there are regional differences as well. In the South rice, in the Northern areas wheat and coarse grains are dominant. Substitution between wheat and rice is only marginally possible as traditional nutritional habits do not allow fast switches in the basic diet.

The consumption of oils and sugar can be expected to increase sufficiently in the future as production is going to be forced, and domestic demand is high (One factor of increasing oil supply might be the boosting of corn production as well.).

Although meat consumption has increased dramatically (70% between 1976 and 1980) and reached 12kg/year/cap in 1980, consumption level of animal proteins is still very low. Milk consumption is only 1.1 kg/year/cap (1980). Additionally 2.1 kg eggs are consumed cap/year. (This is only about 42 pieces a year!). Improved supply of animal proteins can be expected also in the future, but it is not probable that the enormous development in the meat sector of recent years could continue.

The rapid improvement in the nutritional situation in the last five years was enabled by fast general economic growth. Gross value of output of Chinese economy has increased 12.3% in 1978, and although the growth was slowed down (8.5% in 1979 and 7.2% in 1980),§ is still very high by international standards.

Personal incomes increased substantially as well: the average distributed income among commune members developed as follows**

(Y/member/year)	
1970	59.5
1975	63.2
1976	62.8
1977	65.0
1978	74.0
1979	83.4

The personal incomes of members could have increased even more as encouraged private producing activities resulted in increasing incomes from these sources.

As the gap between raised procurement prices and retail prices is subsidized by the state (only consumer prices of meat were increased), the purchasing power of rural and urban population became 34% higher in 1980 than in 1978.* One should stress however, that regional differences in incomes and thus also in consumption might be quite high. The alleviation of these differences is one of the most difficult political tasks of the next years.

* At this estimation we have assumed that 10% of gross production can be accounted for seed usage and waste, there are no stock changes and that feed usage is between 7 and 11 % of available grains.

§ Source: USDA ESS

** SSB, 1980

1.2.5. Foreign Trade of Agricultural Commodities

Foreign trade policies concerning agricultural products are basically determined by three factors:

1) Economic and political decisions affecting production, distribution and consumption of farm products.
2) Weather and other natural influences on farm production; and
3) Availability of foreign exchange

Factors mentioned under 1) and 2) obviously determine the availability of agricultural products. Needs for imports and possibility of exports depend on how far domestic production is able to meet domestic demand, how far surplus have been produced as well. The realization of foreign trade requirements, as already discussed earlier, is a function of how foreign trade can, at least on average, be balanced over several years.

China's agricultural trade in the last decade is shown in Table 8. The value of total agricultural trade was shown in Table 2. It is worthwhile to mention that grain imports came up for 40-45% of total imported value, while the second largest agricultural import commodity, natural textile fibers, account for about 20% of imported value.

Table 8. Trade in major agricultural commodities* (1000 m.t.)

Imports	1971	1972	1973	1974	1975
grains	3128	4642	7642	6790	3459
cotton[2]	122	237	410	380	164
soybeans	0	2	255	619	36
soybean oil	0	10	58	0	11
sugar[3]	464	749	563	411	313
Exports					
rice	924	899	2142	1983	1440
soybean	460	370	310	340	330

Imports	1976	1977	1978	1979	1980	1981[1]
grains	2061	6838	9309	10867	13546	13.4
cotton[2]	142	348	479	845	697	N/A
soybeans	25	364	105	532	665	N/A
soybean oil	13	166	108	112	120	N/A
sugar[3]	635	1750	1408	996	977	N/A
Exports						
rice	1446	1023	1373	1095	1000	600
soybean	178	120	101	320	125	N/A

Source: different USDA publications
1) preliminary or estimated
2) marketing year beginning 1 August
3) new value

The two main factors of export earnings are live animals (meat and fish) with over 20% of total exported value, and grains, also about 20 %. Both fruits and vegetables and natural textile fibers come up for about 10-15% of agricultural export value.*

*source: CIA ER publications

The main trade partners of China are: the USA (grain, soybean and cotton imports), Argentina, Australia and Canada (grain imports), Japan (soybean export) and Cuba (sugar imports).

As both volumes and values show, the main foreign trade factor in China is grain. Imports increased rapidly in the late 1970s.

Due to changed policies, food demand increased sharply in urban and rural areas as well. Reduced pressures on communes by the State Purchasing Organizations resulted in decline of share of production sold to the State in spite of good harvests in 1979 and 1980, and in spite of increased purchasing prices. As Chinese policy is committed to maintain and increase living standards, grain imports became necessary to supply urban areas and also rural areas, which were enabled to specialize in producing cash crops.

Most of the grain imports are wheat (12.6 million tons in 1980). Coarse grains imported are mainly for human consumption. The increase in wheat imports can be explained by increased demand in the Northern areas, where cotton production has been boosted and where wheat is the basic staple food. As rapid growth of cash crop production is going to be continued, wheat imports are expected to continue as well, while imports of cotton, oilseeds and sugar will probably decline. As livestock development programs have been modified and concentrated feeding operation programs have been slowed down, coarse grain imports will not increase significantly. Since China is concerned not to become dependent on world grain markets, and imports of industrial goods and capital equipment have still great importance, grain imports will be limited in the future. On the basis of long-term contracts with several countries it is expected that China will import (mainly food) grains in the range of 12-16 million tons a year in the near future.

1.2.6. Plans for the Eighties

The first plans for the 1980s were elaborated in 1978. As later they were regarded as too optimistic and unrealistic, they were revised in 1980.

The currently valid five- and ten-year plans (until 1985 and 1990, respectively) reflect the policy changes carried out in recent years.

Raising living standards of the people is one of the main objectives. Substantial growth in agricultural production and development of light industry is aimed at to reach this goal. A necessity of a more balanced structural development of the whole economy, and of the agricultural sector, is stressed. With respect to agriculture this means that although grain production is still concerned as the base, boosting of grain production will no be the only objective. On the contrary, using the comparative advantages given by natural conditions with respect to different crops, specialization of regions is being encouraged, to produce the product which fits best to the given conditions.

Thus pastoral areas would not be forced to produce grains, but would be allowed to specialize in animal husbandry. This program requires and in fact relies on the food guarantee of the government for nonfood producing areas.

If it succeeds, this program would lead to respectable yield-increments for almost all crops, and, these are going to be the main source of production growth, since area increases (at least significant ones) are not expected. Although in recent years some area shifts occurred in favor of cash crops, this will not be sustained in the future. Boosting of cash crop production will have to rely on better cropping practices and increasing yields.

Plans considering agricultural input factors also reflect that structural change is going to be one of the main factors of agricultural growth.

As already mentioned in the respective chapter of this paper, no major irrigation plans are foreseen until 1985. A better usage of already existing capacity is strived for. More attention will be paid to soil erosion, salinization, water contamination, etc. resulting from improper irrigation practices.

In the second half of this decade some greater irrigation projects are planned to be realized (regulation of the Yellow River, etc.).

Rapidly growing application of chemical fertilizer has been the most important factor of yield increments. In the future, application of chemical fertilizers will not grow with the same speed (no new big plants are under construction, inefficient small-scale factors are going to be closed down). But, as better composition of fertilizer nutrients applied is aimed at, (at present nitrogen fertilizers dominate) application of chemical fertilizer - although in a changed manner - still can serve as a main factor of growth.

Mechanization of agriculture will be slowed down with the exception of some areas (the North-Northeastern grain base). Proper maintenance (supply of spare parts!), proper management and proper application of machinery (tractors should not be used for transportation, etc.) is stressed.

Most probably mechanization has lost emphasis, because it is a critical point in the development of a labor-abundant economy. The growth of population and labor force is still the basic question. As according to the plans investment rate should drop to 15% of the national gross value added, the possibility of creating new jobs in urban areas will be stronger constrained. This means that most increment in the labor force should be swallowed by the rural sector. Unless birth control programs succeed in rural areas as well (but perhaps even then, as in recent years birth rates were quite high) unemployment might become a serious problem in Chinese agriculture.

The other critical input factor will be the application of scientific results. How education, research and dissemination of results will succeed, will influence development. As Chinese authorities are conscious of this fact, they plan to establish a comprehensive system for the development of agricultural science, technology and education. This integrated system of research and education is going to be regionally organized and specialized to ease dissemination of new findings.

With these plans for changing the structure of agricultural production and developing the input factors, the following production plans have been elaborated for 1985 and 1990 by the State Agricultural Commission Planning Bureau:

Table 9. Planned Production Quantity of Main Crops (million m.t.)

Crop	1985	1990
Grain	375	425
Cotton	3.0	3.35
Oilseeds	8.0	9.00
Meat	14.0	18.5

The gross value added of agriculture should increase by 4% annually between 1981 and 1990. This, including expected increases of sideline enterprises, should enable to grow present incomes to 110-120 million yuan in 1985 and to 150 million yuan in 1990.

2. DESCRIPTION OF THE MODEL

2.1. Basic Characteristics of the Model

The model covers the whole Chinese economy, describing production, consumption and foreign trade of the agricultural sector (aggregated into nine 'commodities'), and the nonagricultural sector (10th 'commodity'). The model is dynamic, operating with one-year time increments. Results of one year's economic performance influence the next year's developments.

It is descriptive in character, concentrating on basic relationships of food (mainly grain) production. Normative features are introduced by government policies, determining required levels of food consumption, investments and grain stock levels.

The first idea was to model Chinese agriculture as one commune, maximizing some utility function of its members and supplying some delivery obligations for the nonagricultural sector. This idea had to be dropped however, since neither the rate of deliveries nor the bonus prices (prices paid for goods sold to the state above the deliveries) nor taxes, etc. were known. How much of the payment in the communes is in kind is also an open question. Thus, another approach had to be chosen: without including the institutional framework of production, agricultural production is investigated as depending on levels of input factors and on some exogenous policies. Food consumption is also taken as basically determined by the food ratios, although some deviations are allowed.

The sample period covers the years 1962-76, but for some variables only shorter time series were available. Even in the cases where longer time series of data exist, they could not always be used for estimation purposes. This is because the economic consequences of the Cultural Revolution result in severe gaps in the time series of economic variables. In these cases shorter series were used. Unfortunately, our sample period doesn't contain the last years of the past decade, when considerable structural changes have been carried out. This fact caused some difficulties at ex-post projection runs, which will be described later. But as the required commodity aggregation by the FAP Basic Linked System (BLS) could be still best supplied by data of the FAO Supply Utilization Accounts, which are available for the given sample period, this had to be used. At some critical points, however, in some simulation runs exogenous adjustments were carried out (e.g. food consumption levels, grain areas).

2.2. Aggregation

As the model is mainly based on the FAO Supply Utilization Accounts (SUA) and has to give outputs which are compatible with the models of the FAP basic linked system, the aggregation used in the Chinese Agricultural Model (CHAM) is essentially the 10-commodity aggregation of the SUA used in other condensed-version models.* The commodities and their units of measurement are:

*A short description of the SUA and its aggregation is given in Fischer and Frohberg, 1980.

Table 10. Commodity List

	Commodity	Unit of Measurement
1.	Wheat	1000 m.t.
2.	Rice, milled	1000 m.t.
3.	Other cereals	1000 m.t.
4.	Bovine and ovine meats	1000 m.t. (carcass weight)
5.	Dairy products	1000 m.t. (fresh milk equivalent)
6.	Other animal products (incl. pork)	1000 m.t. (protein equivalent)
7.	Protein feeds	1000 m.t. (protein equivalent)
8.	Other food	mill. US $ (1970)
9.	Nonfood agricultural production	mill. US $ (1970)
10.	Nonagricultural production	mill. US $ (1970)

The only actual difference consists of the separate treatment of cotton production, as this is of basic importance in China. Cotton is handled as the 18th commodity. Commodities 11-17 are the same as in the so-called extended commodity list elaborated by Fischer and Frohberg, namely:

11. Fat of bovine and ovine animals
12. Fats and oils of other animals
13. Meat meal
14. Fish meal
15. Skin, wool and hair of bovine and ovine animals.
16. Skin and hair of other animals
17. Aggregate of bovine and ovine meat and dairy production.

Commodities 11-17 are differentiated for only because of technical reasons, all results are given for the 10 commodity aggregation.

2.3. The Structure of the Model

The model consists of five blocks, namely:

1. population
2. government
3. production
4. exchange and
5. accounts blocks

The relationships of the blocks and their contents can be figured as follows:

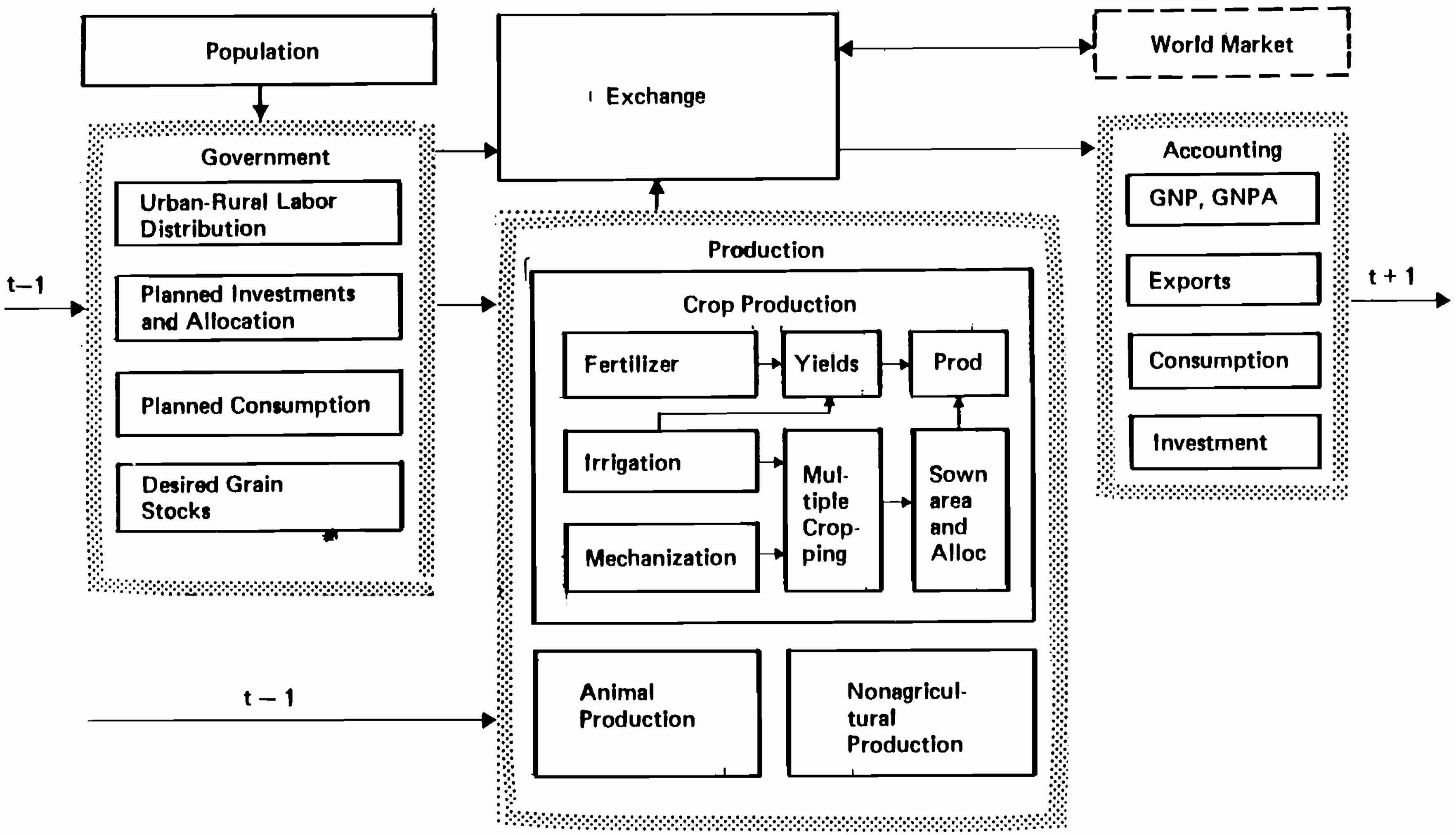

Figure 2. Structure of the Chinese Agricultural Model

The population block contains three exogenously given series of population size. This information is used in the government block, where urban-rural population distribution and food requirements are determined. In the government block planned gross investments and their allocation between agriculture and the nonagricultural sector are computed according to assumed policies. Planned consumption of nonfood items and planned levels of grain stocks are also determined in this block.

In the production block, inputs to agricultural production, namely mechanization, irrigation and fertilizers (both chemical and organic) and land are computed first. Given these, the index of multiple cropping and the yields of crops can be estimated. The size of animal stocks is connected to the grain availability for feed. Nonagricultural consumption is determined as a Cobb-Douglas function of nonagricultural labor and capital.

In the exchange block, supply from domestic production is compared to planned consumption, investments and grain stocks. According to a predetermined priority order (which expresses political priorities) and at given intervals around the planned levels, deviations from the planned levels of grain stocks, consumption and investments are allowed.

During the computation of these deviations, influences of the world market prices and the planned deficit of balance of payments are considered as well. As a result, exports and imports can be computed.

The accounting block of the model collects results of year t, such as: the realized food and nonfood consumption, realized investments, balances of capital stocks, protein and calories consumed, grain stocks, gross national product of agriculture and of nonagriculture, etc.

2.3.1. The population block

At present the population block is an exogenously given part of the model, containing time series of three population estimates and those of working age population according to the three different estimates.

As no official time series about the size of total population is available for the whole of our sample period and the few official figures published lie between two estimates from the USDC, prepared by J. Aird, his three alternative population estimates were used. These estimates are generally accepted in the literature and supply the age structure of the population as well. Thus, taking persons between the ages of 15 and 60, and using the correction term elaborated by F. Crook,we get the working-age population.*

Although in the last decade some birth-control policies have been introduced to stop rapid population growth, they have failed. According to the 10-year plan, valid until 1985, the population growth rate should have decreased to 0.5 percent by 1985. This goal, as can now be established, was not reached; particularly in rural areas the growth rate was much higher (not only for traditional reasons, but also because of a practical one: there are no adequate retirement schemes in rural areas, only in the cities, and thus to ensure a living in old age, people have many children).

According to most recent information, the People's Congress approved a plan to stabilize population by about 2000. This would seem to make massive campaigns necessary to reduce birth rates, and in order to reach this goal,

*Aird's estimates are supported in part by Chinese official data as well; the published data about the school-age population, for instance, fits in very well with Aird's estimated age structure.

most probably combined socio-economic measures will be taken.

As the rural-urban distribution of population in China has been highly influenced by political decisions in the last decades, and this trend will probably continue also in the future, this is treated as a policy variable and determined in the government policy block of the model.

2.3.2. The government policies block

2.3.2.1. *Urban-rural labor distribution.*

We follow the method of Th. Rawski (1979) who has worked out a detailed labor market analysis for the two benchmark years of 1957 and 1975, based on Aird's population estimates and a broad range of other information. We also adopt Rawski's opinion that the rate of rural-urban migration is mainly dependent on how many jobs can be created in the nonagricultural sectors. This means that the labor force not employed outside of agriculture has to be absorbed here. Actually, agriculture has been able to do this in the past, as China's agriculture is very labor-intensive. However, this has resulted in underutilization of labor.

Thus we use the following method to calculate urban and agricultural labor force. We take Aird's estimates about the age class 15-60, correct it for the working-age population with the term of 0.7412, as given by F.W. Crook. We use the explicit growth rate (5% annually in most of the runs) for the number of urban labor force. Deducting this from the total, we receive agricultural labor force.

This procedure seems to work quite well, as it produces results which lie close to official figures. For 1979 for instance we receive the following figures (in brackets we given the respective official data): Total population, Aird's low estimate: 972 million [970]; total labor force: 401.5 million [405.86]; urban labor force: 106.4 [111.6]; agricultural labor force: 295.1 million [294.25].

We assume two growth rates of number of jobs in the nonagricultural sector. One is the past average growth rate and another a higher one, which is taken by Rawski as the highest possible growth rate.

Thus, the urban-rural labor forces are computed in the model as

$$ULAB(k,t) = (1. + \alpha_{Ln}) * ULAB(k,t-1) \qquad (2.1)$$

$$RLAB(k,t) = TLAB(k,t) - ULAB(k,t) \qquad (2.2)$$

where

ULAB(k,t) is the urban labor force according to the k-th population estimates in year t in 1000 persons

TLAB(k,t) is the total labor force computed according to the age distribution of k-th population estimate in year t in 1000 persons

RLAB(k,t) is the rural labor force according to the k-th population estimate in year t in 1000 persons

α_{Ln} = 0.050 if past average growth rate is assumed
0.075 if a faster outmigration is assumed

Adapting Rawski's estimate that the labor participation rate is 50% in urban areas, we can compute urban and rural population as well.

The higher outmigration of agriculture is coupled in the model with an investment allocation policy which creates enough jobs in urban areas.*

*Urban areas mean here agglomerations with population over 2000 of whom the majority are

2.3.2.2. *Planned investments and their allocation*

Planned total gross investments are determined in the model by the function

$$PGI(t) = a + bGNP(t-1) \tag{2.3}$$

where

$PGI(t)$ is the planned total gross investment in year t

$GNP(t-1)$ is the gross national product in year t-1.

When estimating the parameters of the function, using past data of variables, it was assumed that past planned values and realized values were the same.

As data on gross investments are only available for a period of nine years (1965-74) and there is some evidence that in the last years investments were higher than in the sample period, the 'b' parameter of the function is sometimes used as a policy parameter.

Little is known about how much of total investments was allocated to agriculture. Thus, it was assumed that for the sample period the share of agriculture was 20 percent of total gross investment. One should stress that this assumption is very arbitrary, and cannot be controlled easily. Capital-output ratios of agriculture and nonagriculture computed using this assumption are comparable to some developing countries, however. Thus the allocation of investments in the model is:

$$PGIA(t) = \alpha_{AI} * PGI(t) \tag{2.4}$$

$$PGIN(t) = PGI(t) - PGIA(t) \tag{2.5}$$

where

$PGIA(t)$ is the planned investment to be allocated to agriculture

$PGIN(t)$ is planned investment to be allocated to the nonagricultural sectors

α_{AI} is a policy variable, for the sample period $\alpha_{AI} = 0.20$

2.3.2.3. *Planned consumption*

As in China the basic food items, such as grains and vegetable oils are rationed, it was attempted to compute these ratios from past food consumption figures. Food consumption data from the FAO Supply Utilization Accounts and the three series of population were used to compute the per capita food consumption. There has been a slight growth in per capita consumption of wheat, but the consumption of rice and coarse grains has not increased during the data period. As grain consumption might have increased more between 1977 and 1980 than given by the trends, in some simulation run exogenous growth rates were introduced. No increase could be discovered in bovine meat consumption; but there is a slight trend in the consumption of dairy products and in the category "other meats" (most probably due to higher consumption of pork). As meat (mainly pork) consumption has increased remarkably in the late 1970s, not included in our sample period, in some simulation runs higher, exogenously given growth rates were introduced. The consumption of the commodity 'other food' increased also, mainly because of higher vegetable consumption. For all

engaged in nonfarm activities. This means that workers of rural small-scale industries are considered as agricultural workers.

the food commodities of the model (in the 10-commodity aggregation i=1,2...8) the per capita consumption values, if they are essentially constant or, if a trend in the per capital consumption does exist, the trend values are interpreted as planned per capita consumption. Multiplying by the population number, total planned food consumption per commodity is computed:

$$PC(i,k,t) = PFC(i,k,t) * POP(k,t) \quad i = 1,2,...8 \tag{2.6}$$

$PC(i,k,t)$ is the planned food consumption of commodity i in FAP units in year t for population estimate k

$PFC(i,k,t)$ is the per capita food consumption of commodity i in FAP units in year t for population estimate k

$POP(k,t)$ is the number of population according to the k-th estimate in year t

The per capita planned consumption values are determined as mentioned by the trends or by constant values, as:

$$PFC(i,k,t) = a + b \ln t \qquad i = 1,5,6,8 \tag{2.7}$$

$$PFC(i,k,t) = const \qquad i = 2,3,4,7 \tag{2.8}$$

Planned consumption of nonfood commodities is computed as

$$PC(i,t) = (1. + \alpha_{PCi}) * PC(i,t)_{-1} \; i = 9,10 \tag{2.9}$$

where

α_{PCi} is the planned growth rate of consumption of commodity i, a policy variable

2.3.2.4. *Desired grain stocks*

In China state authorities have often recommended that communes and peasants keep grain stocks to secure their own consumption for a given time. Depending on the units referred to, the time-spans recommended for storage of grain differ, because of the differences in storage capacities of units.

Total grain stocks for 1973 were estimated at 40 million tons by G. Etienne (1977). Assuming that grain stocks are kept according to the grain consumption patterns of population, this stock has been divided into stocks of wheat, rice and coarse grains. Per capita stocks were computed and interpreted as desired stocks.*

$$DST(i,k,t) = d_i * POP(k,t) \qquad i = 1,2,3 \tag{2.10}$$

where

$DST(i,k,t)$ is the desired stock of grain i at population k

d_i desired stock per capita as computed or given as policy variable.

This is a very crude procedure to describe how grain stocks develop. However, about this issue information is extremely poor. In the model the absolute size of stocks doesn't play any significant, only formal role. Only stock changes are of importance. In the exchange module, described later, the question is, if the planned growth of stocks can be realized, or how far they can be really

*In 1973 stocks might have had an average level. This is supported by a calculation where deviations from trend of total grain consumption were interpreted as stock changes. A series of stock levels could be created in this way, and also per capita stocks for several years. These show the year 1973 to be an average one with respect to grain stocks.

increased.

2.3.3. Production block

2.3.3.1. *Crop production*

Inputs to agricultural production

The basic input to crop production, land is scarce in China and in the last decade, it has been increased mainly by intensifying multiple cropping. Thus, before we turn to land, we have to deal with input factors which are decisive in increasing multiple cropping.

Mechanization is important in peak seasons, i.e. when one crop is harvested and the next one is sown. This period could be shortened by a greater use of machines, mostly harvesters and rice transplanters. Unfortunately, time series long enough for our purposes are available only about the numbers of tractors used; thus, in the model these represent the level of mechanization.

The other source of increasing multiple cropping is irrigation. Although campaigns of building canals and dams have gone on in the last decades irrigation is still a serious problem in China. The introduction of appropriate techniques is urgently needed. (Canals built by intensive use of almost only human labor have siltated in a short time; the excessive number of tube wells have caused a lowering of the groundwater table, etc.) The regulation of the Yellow River would add 2.88 million hectares to the irrigated area (which was about 48 million hectares in 1977) in 1990, when the project is planned to terminate.

The following equations are used in the model to describe development of inputs other than land:

$$\frac{TRCT(t)}{TC(t)} = \frac{a_1}{1. + a_2 e^{-a_3 t}} * KA(t-1) \tag{2.11}$$

$$PIEQ(t) = a_1 * KA(t-1)^{a_2} \tag{2.12}$$

$$AIRR(t) = a_1 + a_2(1. - e^{-1/t}) * PIEQ(t) + a_3 KA(t-1) \tag{2.13}$$

where

$\frac{TRCT(t)}{TC(t)}$	is the number of tractors in use in 1000 of 15 HP units in year t per ha of cultivated area
$KA(t)$	is capital stock of agriculture at the end of year t in mill. $ US
$PIEQ(t)$	is the powered irrigation equipment in use in 1000 HP in year t
$AIRR(t)$	irrigated area in year t in mill. ha
$TCL(t)$	is the cultivated area in year t in mill. ha

In the base run it was assumed that in the next years investments to irrigation will be forced, and that irrigation depends on two factors, namely on the powered irrigation equipment used and other capital stocks like dams, canals, etc. In other runs irrigation is influenced by expected policy measures.

The second source of growth of production has been increasing yields, which is the result of better fertilization, better irrigation and use of better varieties. In our modeling framework we do not deal with the problem of introducing new varieties. This is a complex problem of investment to research, institutional system of disseminating new results, etc. and lie outside the scope of our investigations.

Application of chemical fertilizer is fast increasing in China, but is still at a low level, and organic fertilizer is still used intensively. (In 1977 chemical fertilizer application was 64 kg nutrient/ha, and organic fertilizer application was 136 kg nutrient/ha). Rapid increase in the use of chemical fertilizers will also serve in the future as the main source of increasing yields. Organic fertilizers, however, will not be made available in such rapidly increasing amounts, as their sources are constrained. The other problem of application of organic fertilizers is that this is a very labor-intensive activity, and although this was widely utilized to absorb labor force into agriculture in the past, it is a question to what extent this will be possible and/or necessary in the future.

As China is a big fertilizer importer, the application of chemical fertilizers depends both on domestic production and on imports. This is modeled as follows:

$$FPR(t) = a + bKNA(t-1) \quad (2.14)$$

$$FAP(t) = a_1 + \frac{0.45}{1. + a_2 e^{-a_3(t-1959)}} \quad (2.15)$$

$$FOR(t) = 0.011 * NS(t) + 0.014 * [HM(t) + DM(t)] + 0.0043 * RM(t) \quad (2.16)$$

where

$$NS(t) = 0.5 * (RPOP(t) * 0.9 + UPOP(t) * 0.5) \quad (2.16a)$$

$$HM(t) = 1.8 * PST(t) \quad (2.16b)$$

$$DM(t) = a_1 * PY(4,t) \quad (2.16c)$$

$$RM(t) = a_1 + a_2(t) \quad (2.16d)$$

$$FT(t) = FAP(t) * TSOWN \quad (2.17)$$

$$FIM(t) = FT(t) - FPR(t) - FOR(t-1) \quad (2.18)$$

where

$FPR(t)$ is the production of chemical fertilizer in year t in mill. m.t. of nutrients

$FT(t)$ is the total fertilizer applied in year t in 1000 m.t. of nutrients

$FAP(t)$ is a trend of application of fertilizers (including both organic and chemical fertilizers), assumed to be followed, given in nutrient values kg/ha. The asymptote of the fertilizer application trend is the Japanese level of 1978.

$FIM(t)$ fertilizer imported in year t in mill. m.t. of nutrients.

$FOR(t)$ is the organic fertilizer applied in year t in mill. m.t. of nutrients
The constants applied in the equation (2.16) are taken from Tang's study.

$PST(t)$ is the number of pigstock in mill. animals in year t

$NS(t)$ is the night soil produced in year t in million mt gross weight

$HM(t)$ is hog manure produced in year t in million mt gross weight

$DM(t)$ is draft animal manure produced in year t in million mt gross weight

$RM(t)$ is other organic manures (green manure, oil cake, compost, mud and others) produced in year t

$UPOP(t)$ is the urban population in year t in millions

$RPOP(t)$ is the rural population in year t in millions

$PY(4,t)$ is the draft animal production in year t (representing the draft animal stocks, which are no computed explicitly in the model)

As labor in Chinese agriculture is not always used economically and data about effective labor is not available, it is not considered in the model.*

Land and its allocation

Although cultivated area has slightly declined in the last years, in most runs we keep this variable constant in the model, as time series about the exact size of the decline were not available for us. It is, however, possible to introduce any rate of reduction or growth (as, e.g. the plan of reclamation of 8 million ha until 1985). Unfortunately, missing information hinders us to account for reclamation costs.

As already mentioned in the previous chapter, multiple cropping plays a central role under these circumstances and has already reached a high level - in 1979 the index of multiple cropping was 149. Multiple cropping can be increased basically in two ways: by mechanization and by increased irrigation. It is determined in the model as

$$MCI(t) = a_1 + a_2 e^{\frac{-1}{t}} * \left(\frac{TRCT(t)}{TCL(t)}\right)^{a_3} \left(\frac{AIRR(t)}{TCL(t)}\right)^{1-a_3} \qquad (2.19)$$

Total sown area is then computed as:

$$TSOWN(t) = TCL(t) * MCI(t) \qquad (2.20)$$

where

$TSOWN(t)$ is the total sown area in year t in mill. ha

$MCI(t)$ is the index of multiple cropping in year t, defined as the ratio of total sown area to cultivated area

$TCL(t)$ total cultivated land in mill. ha in year t

The allocation of land to different crops has shown the basic effort of producing enough grain. Communes were pushed to grow grains even if some other crops could have been produced more economically.

The area shares of different crops have not changed significantly. Almost 70 percent has been sown to grains and a relatively stable share has been used to produce cotton during our sample period. One should stress again that the allocation of land was very often influenced by noneconomic factors.

In the model the area shares of the different crops are handled as autoregressive processes (of first and second order) and thus are computed according to the formula

$$ARS(i,t) = a_{1i} + a_{2i} * ARS(i,t-1) + a_{3i} * ARS(i,t-2) \qquad (2.21)$$

for i = 1, 2, 3, 7, 8, 9, 18

and the area of crop i is

*Agricultural GDP/agricultural laborer declined from 1.46 Y/day to 0.94-1.2 Y/day between 1957-1975.

$$AR(i,t) = ARS(i,t) * TSOWN(t) \tag{2.22}$$

As the autoregressive schemes project the area shares independently, there is no guarantee that these will add up to one. Thus the AR'(i,t) areas have to be corrected to add up to TSOWN(t).

The correction procedure takes account of the self-sufficiency rates, and of the area shares of the different crops. The underlying assumption is that self-sufficiency of each crop is strived at and that corrections should be proportioned to the area shares, reflecting the relative importance of the different crops.

Let us denote

$$DA(t) = TSOWN(t) - \sum_i AR(i,t) \tag{2.23}$$

a) if $DA(t) > 0$

$$AR(i,t) = AR(i,t) + z(i,t) * DA(t) \qquad \text{for } i \in M \tag{2.24}$$

M being the index set of imported crops

$$AR(i,t) = AR(i,t) \qquad \textit{otherwise} \tag{2.25}$$

and where

$$z(i,t) = \frac{w(i,t)}{\sum_j w(j,t)} \tag{2.26}$$

w(i,t) being calculated as

$$w(i,t) = \frac{IMP(i,\ t-1)}{PY(i,\ t-1)} * \frac{AR(i,\ t-1)}{TSOWN(t-1)} \tag{2.27}$$

b) if $DA(t) < 0$

$$AR(i,t) = AR(i,t) + z(i,t) * DA(t) \qquad \text{for } i \in E, \tag{2.28}$$

E being the index set of exported crops

$$AR(i,t) = AR(i,t) \qquad \textit{otherwise} \tag{2.29}$$

and where

$$w(i,t) = \frac{EXP(i,t-1)}{PY(i,t-1)} * \frac{AR(i,t-1)}{TSOWN(t-1)} \tag{2.30}$$

$$z(i,t) = \frac{w(i,t)}{\sum_j w(j,t)} \tag{2.31}$$

where

$PY(i,t)$ is the production of commodity i in FAP units in year t

$EXP(i,t)$ is the net export of commodity i in FAP units in year t

$IMP(i,t)$ is the net import of commodity i in FAP units in year t

In some simulation runs a decline of the grain areas has been introduced for some years. Thus area devoted to cash crops has been increased.

Yields

When modeling crop production, we assume that yield increments have two sources: increased use of fertilizers and irrigation. Although the use of improved varieties might have had considerable impact on yields, this could not be taken into account.

Thus for the main crops (wheat, rice, coarse grains and cotton) the following yield functions have been estimated:

$$Y(i,t) = a_{i1}\left(\frac{FAP(t)}{TSOWN(t)}\right)^{a_{i2}}\left(\frac{AIRR(t)}{TCL(t)}\right)^{a_{i3}} \qquad (2.32)$$

where

$Y(i,t)$	is the yield of crop i in year t in m.t./ha
$FAP(t)$	is total (organic and chemical) fertilizer applied in year t in mill. m.t. of nutrients
$TSOWN(t)$	is the total sown area in year t in mill. ha
$AIRR(t)$	is the irrigated area in year t in mill. ha
$TCL(t)$	is the cultivated area in year t in mill. hectares

Surprisingly enough, the a_3 parameter of the function is not statistically significant in the case of rice , the standard error is bigger than the parameter itself. This might be a result of the crude assumptions made, but for rice this might have a plausible explanation as well. According to USDA information irrigation has been developed mainly in the Northern and Northeastern areas between 1957 and 1975. Irrigated area almost doubled in these regions during this period, whereas other regions (except the Southwest) have not increased significantly their irrigated areas, some of them (e.g. Central China) might even have had less irrigated area in 1975 than in 1957. The Northern and Northeastern areas produce most of China's wheat and coarse grains; rice is usually produced in the East, Central and Southwest China. As we have only average yield data for the whole country and time series for total irrigated area, it is possible that the regional differences in irrigation development and dominant crops discussed result in this behavior of the parameter. Thus, irrigation has been dropped as a production factor in the yield function for rice, and only fertilizer is used as explanatory variable.

In the cases of oil crops (excluding cottonseed), other food crops (excl. oil crops) and nonfood crops, other than cotton, instead of a production function simple trends are used to determine yields. This is so because information is weaker for these compound groups of crops, and no assumption could be made about input factors. Thus yields of these commodities :

$$Y(i,t) = a + b * \ln t \qquad i = 7,8,9 \qquad (2.33)$$

where

$Y(i,t)$ is the yield of crop i in year t in FAP units, and t is the calendar year.

Production

Thus, crop production is computed as:

$$PY(i,t) = AR(i,t) * Y(i,t) \qquad \text{for } i = 1,2,3,18 \quad (2.34)$$

where

$PY(i,t)$ is the net production of crop i (net of seed and wastes) in mill. metric tons in year t

$AR(i,t)$ is the area allocated to crop i in year t in 1000 ha

Y(i,t) is the yield of crop i in year t in m.t./ha

Production of commodities 7, 8 and 9 according to the FAP commodity list can be computed as:

$$PY(7,t) = AR(7,t) * Y(7,t) + \beta_1 * PY(18,t) \quad (2.35)$$

$$PY(8,t) = AR(8,t) * Y(8,t) + \beta_2 * PY(18,t) * P70 + \beta_3 PY(7,t) * PV70 \quad (2.36)$$

$$PY(9,t) = AR(9,t) * Y(9,t) + 0.5 * PY(18,t) * PC70 \quad (2.37)$$

where

PY(i,t) is production of commodity i in year t in FAP units

β_1 is constant, computed as protein content of cake of cottonseed extraction rate cake/cottonseed

β_2 is the extraction rate of cottonseed oil

P70 is the constant (1970) price of oil of cottonseed in US $ /m.t.

β_3 is a parameter expressing the amount of vegetable oils produced as 'byproducts' of protein feeds (excl. cottonseed) assuming that the mix of crop in the composite does not change.

PV70 is the constant (1970) price of vegetable oils in US $/ m.t.

PC70 is the constant (1970) price of cotton lint in US $/m.t.

Cotton lint production is taken as half of weight of cotton seed production.

2.3.3.2. *Animal production*

As Chinese traditional diet has been based on grains, and producing enough grains has taken most of the peoples' effort, meat production and consumption in spite of remarkable increases in recent years are still at very low levels.

Animal production in China means mostly pig production in backyards, and fish production in fishponds run by production brigades. Although in recent years some large-scale hog and chicken farms have been installed (partly with imported technology), the extent of these programs is not known. Another unknown factor is the amount of support the government will provide for the development of large-scale animal husbandry.

Although the size of pig stock is a function of several (and also political) decisions, we constrain ourselves only to the most basic determinant, the feed grain availability.

$$PST(t) = a + b * FEGR(t-1) \tag{2.38}$$

where

PST(t) is the stock of pigs kept in year t in 1000 head

FEGR(t-1) is the volume of grains fed to animals in year t-1, 1000 m.t.

Feed requirements of animal stocks are computed as in the other models of the FAP basic linked system (see Fischer and Frohberg, 1980), as no special information is available for China.

The yields reached in animal husbandry are described by simple trends fitted to data given by the FAO Supply Utilization Accounts.

$$Y(i,t) = a + b * lnt \qquad i = 6 \tag{2.39}$$

where

Y(i,t) is the yield in m.t. of carcass weight/animal, net of breed and waste in year t

Planned yield increases in the animal husbandry and hypothetical feeding patterns implied by the changed mode of animal breeding are introduced as well (see description of simulation runs in Chapter 3 and also Appendix 2).

As bovine animals are kept mainly as draught animals, and are usually fed on pastures and with forage crops which are not included in the model, the production of bovine meat and dairy production are included in the model as simple trends.

Total production of animal categories is computed as:

$$PY(4,t) = a + b \ln t \tag{2.40}$$

$$PY(5,t) = a + b \ln t \tag{2.41}$$

$$PY(6,t) = PST(t) * Y(6,t) * PR61 * PROT6 \tag{2.42}$$

where

$PY(i,t)$ is the production of commodity i in year t in FAP units

$PR61$ is a correction term, increasing the production of commodity 6 for production of poultry and fish

$PROT6$ is the average protein equivalent of meat categories included in commodity 6

When meat production is determined, joint products have to be considered as well. In addition to meat and dairy products from the commodity 'bovine and ovine animals' also fats, meat meals and animal fibres (skin, hair, wool) are derived as byproducts. For the commodity 'other animals' the byproducts fat, fishmeal and animal fibres (skin, hair) are derived. Based on historical data joint production coefficients are calculated as described in Fisher and Frohberg (1980). The byproducts are then added up to the crop production part of the commodities 7,8 and 9. (i.e., to the protein feeds of crop origin we add meat meal and fishmeal; to 'other food' we add animal fats and to the 'nonfood' agricultural products we add fibres of animal origin.)

2.3.3.3. *Production of nonagriculture*

The production of all sectors other than agriculture is aggregated into only one aggregate, which we call the 10th commodity. We assume that this production can be described by a production function of Cobb-Douglas type with constant returns to scale.

$$PY(10,t) = a_{NA} * KNA(t-1)^{a} * ULAB(k,t)^{1-a} \qquad (2.43)$$

where

$PY(10,t)$	is the production of nonagricultural sectors in year t in mill. of constant (1970) US $
$KNA(t)$	in the capital stock at the end of the year in year t in nonagriculture, measured also in mill. of constant (1970) US $
$ULAB(k,t)$	is the number of urban laborers according to the population estimate k as determined in the government policy block

2.3.4. Consumption and exchange block

In this block domestic supply of food and nonfood agricultural products and that of the nonagricultural product is compared with the demand for these items. Foreign trade activities are introduced to fill up gaps between supply and demand if necessary and possible at the prevailing world prices and predetermined balance of foreign trade. A relatively simple balancing routine is used* to calculate exports and imports. Planned consumption levels, planned investment and desired grain stocks are treated as target demands, from which, however, deviations are allowed. A strict priority order of targets to keep realized values as close as possible to the target values is predetermined. Allowed deviations from target values, and the specified priority order and the exogenously given balance of trade express political preferences.

Formally written, the procedure is as follows:
Find $\lambda_i \in [\lambda_i\ \boldsymbol{min},\ \lambda_i\ \boldsymbol{max}]$, such that

$$p^{w} Q\lambda = p^{w}y + k \qquad (2.44)$$

will be fulfilled, where the structure of the Q-matrix and of the y vector is:

*The same routine is used in FAP's Hungarian Agricultural Model and in the model for the CMEA countries, both developed by C. Csaki (1980).

$$
p^w * \begin{bmatrix}
PC_1 & & & & & PF_1 & DS_1 & & \\
PC_2 & & & & & PF_2 & & DS_2 & \\
PC_3 & & & & & PF_3 & DS_3 & & \\
 & PC_4 & & & & & & & \\
 & PC_5 & & & & FP_5 & & & \\
 & PC_6 & & & & & & & \\
 & & PC_7 & & & PF_7 & & & \\
 & & PC_8 & & & PF_8 & & & \\
 & & & PC_9 & & & & & \\
 & & & & PC_{10} & & & & PGi
\end{bmatrix} * \lambda = p^w \begin{bmatrix}
Y_1 - CINT_1 + S_{1,t-1} \\
Y_2 - CINT_2 + S_{2,t-1} \\
Y_3 - CINT_3 + S_{3,t-1} \\
Y_4 - CINT_4 \\
Y_5 - CINT_5 \\
Y_6 - CINT_6 \\
Y_7 - CINT_7 \\
Y_8 - CINT_8 \\
Y_9 \\
Y_{10}
\end{bmatrix}
\qquad (2.45)
$$

where

- q_{ij} is the target demand for commodity i (planned personal consumption: PC(i), desired grain stock, DST(i). or feed requirement of commodity i: PF(i))
- λ_j is a parameter, expressing how far the target of demand type j can be realized ($\lambda_j = 1.0$ means exact realization of the target)
- p^w is the vector of world market prices
- y is the vector of net domestic supply, and
- k is the exogenously given value of balance of trade.
- PF_i is the feed requirement of commodity i by animal stocks, computed as:

$$PF_i = f_6(i) * PY(6) \qquad i = 1,\dots,8 \qquad (2.46)$$

and CINT(i) is the intermediate consumption of commodity i, computed as:

$$CINT(i) = \alpha_i * PY(i) \qquad i = 1,\dots,8 \qquad (2.47)$$

Planned consumption levels, desired grain stocks and planned investment enter the exchange block as determined in the government policy block. But also feed requirements* by animal stocks enter the block as target demand. It is assumed that a somewhat smaller consumption of feed items than the computed requirement doesn't affect meat production at all, as the difference can be equalized by some feed items not explicitly included in the model. (In fact, wastes, forage products, etc. are widely used in China for feeding animals.) Treating feed requirements as demand allows us the introduction of some competitive behavior between food and feed demands for the same commodity.

When computing net domestic supply of each commodity, we subtract intermediate consumption from the net production. Intermediate consumption is assumed to be a fixed part of production, and was computed in the FAO SUA. (For the nonfood agricultural products we assume that the total production of

*Computed according to the procedure described in the paper by G. Fischer and K. Frohberg (1980).

this commodity is used as input into nonagricultural production.)

In addition, for the three grain products for which stocks also are considered, net domestic supply is increased by last year's stocks.

The λ parameters describe different policies, as the order of succession of changing the value of the parameter from its target value expresses the priority order of keeping the specific target reached (i.e. the later a parameter is changed, the more the planned values in the corresponding columns of the Q-matrix are kept at the target level). The λ_{min} and λ_{max} values express the maximal allowed deviations of targets.

After the proper λ's have been found, the realized consumption can be computed as:

$$RC_i = \lambda_j * PC_i \qquad i = 1,\dots 10 \tag{2.48}$$

realized investments:

$$GINV = \lambda_6 * PGI \tag{2.49}$$

realized grain stocks:

$$ST_i = \lambda_j * DS_i \qquad i = 1,2,3 \tag{2.50}$$

feed consumption of commodity i:

$$F_i = \lambda_j * PF_i \tag{2.51}$$

Net exports are computed as:

$$EX_i = PY_i - CINT_i + ST_{i,t-1} - RC_i - F_i - ST_i \qquad i = 1,2,3 \tag{2.52}$$

$$EX_i = PY - CINT_i - RC_i - F_i - ST_i \qquad i = 4,5,\dots 8 \tag{2.53}$$

$$EX_9 = PY_9 - RC_9 \tag{2.54}$$

$$EX_{10} = PY_{10} - RC_{10} - GINV \tag{2.55}$$

where

EX_i is the net export of commodity i in FAP units, all other symbols as defined above.

2.3.5. Accounting

When realized consumption, investments, stocks and foreign trade have been computed, agricultural and nonagricultural GNP, capital stocks, human grain consumption etc. can be accounted for, before the model moves to the next year.

$$GNPA(t) = \sum_{i=1}^{8} p_i \, [PY(i,t) - CINT(i,t) + (ST(i,t) - -ST(i,t-1)) + EX(i,t) - F(i,t)] \tag{2.56}$$

$$GNPN(t) = (PY(10,t) + EX(10,t)) * EXCH \tag{2.57}$$

$$KA(t) = KA(t-1) * (1 - d_A) + \alpha_{Ai} GINV(t) \tag{2.58}$$

$$KNA(t) = KNA(t-1) * (1 + d_{NA}) + (1 - \alpha_{Ai}) GINV(t) \tag{2.59}$$

$$THC(t) = \sum_{i=1}^{3} RC(i,t) - EX(i,t) \tag{2.60}$$

$$THCC(t) = THC(t) / POP(t) \tag{2.61}$$

$$PROTC(t) = \sum_{i=3}^{8} RC(i,t) * PROTCT_i / POP / 365 \tag{2.62}$$

$$CALC(t) = \sum_{i=1}^{8} RC(i,t) * CALCT_i / POP / 365 \tag{2.63}$$

where

$GNPA(t)$	is the gross national product of agriculture in million Yuan
p_i	is the constant (1970) price of commodity i (or, for commodities for which production is computed in US $, the exchange rate)
$GNPN(t)$	is the gross national product of nonagriculture in million Yuan
$EXCH$	is the exchange rate in 1970 (= 2.4)
d_A	is the depreciation rate in agriculture
d_{NA}	is the depreciation rate in nonagriculture
$THC(t)$	is the total human grain consumption in year t in metric tons
$THCC(t)$	is human grain consumption per capita in year t in kg
$PROTC(t)$	is protein consumption per capita per day in year t
$CALC(t)$	is calorie consumption per capita per day
$PROTCT_i$	is the protein content of a unit of commodity i
$CALCT_i$	is the calorie content of a unit of commodity i

All other symbols are as defined above.

3. MODEL RESULTS

As the model was estimated on the basis of the FAO SUA and our production series ended with 1976, at the very first we made a trial run to see how much the model fails in its original form in describing the years between 1977 and 1981. Of course, we expected that the model would produce high errors, since 1978 and 1979 were years with very favorable weather (the model does not contain weather variables) and because of the great policy changes, influencing production during this period. Afterwards, step by step, we introduced exogenously changes in the model, which represent recent and expected policy changes. These were the following ones:

i) irrigated area does not increase significantly until 1985

ii) the share of grain areas in the total falls by 1% annually until 1985

iii) consumption of wheat and rice increases faster than according to estimated trends,

iv) the increased pig meat consumption was coupled with two hypothetical development paths of changing feeding patterns (a detailed description of these feeding patterns can be found in Appendix 2) and

v) last, we introduced the planned drop of investments to 15% of GNP.

In the first run, were no exogenous changes were introduced, both production and imports were significantly underestimated for the years 1977-81. As long as total grain production, for instance, for the last two sample years, 1975 and 1976, was overestimated by the model by 3.3% and underestimated by 2.6%, respectively, the error for 1980 was 13%. Similarly, the model was not able to follow the increase in the grain imports.

Still, some results of this run are of interest:

Table 10. Production of Grains and Cotton, million m.t.

	wheat	rice(milled)	coarse grain	cotton
1975	38.0	102.5	69.8	3.5
1980	47.4	117.5	74.4	4.2
1985	57.6	133.6	86.5	5.1
1990	66.7	152.0	100.9	6.2

According to these projections, for grains and for cotton, the production plans given in Table 9 seem to be high. For the grains, if we correct the numbers representing milled rice to paddy, we get total grain production of 344 million m.t. and 395 million tons for 1985 and 1990 respectively. Both lower than the plan figures.

Since this run doesn't take account of increased consumption, wheat imports do not increase above 6.9 million tons until 1990, and coarse grain imports reach 3.4 million tons in 1990. Interestingly enough, according to these calculations, high rice exports (more than 10 million tons) would be possible at the end of the decade. This is clearly the result of the fact that our trend estimate of per capita consumption did not show any increase in rice consumption during 1964-1976 (this assumption was changed in a later run).

Still, in spite of the fact that only the past trends of food consumption were considered (which are smaller than the real ones) the calorie intake per capita increases from 2350 calorie/day in 1970 to 2600 calories in 1990.

The growth of both agricultural and total GNP is slowing down. As long as agricultural GNP is increasing 2.8% annually between 1980 and 1985, this is declining to about 2.7% during the next five years. This is less than expected, most probably because the shift to cash crops and the increases planned in meat consumption have not been introduced in this run. The decline is sharper in the total GNP. As long as between 1975 and 1980 the average annual growth was 5.88%, this declines to 5.68% until 1980 and to 5.32 until 1985.

In the run when we consider additionally that no significant increase of irrigated areas is expected until 1985, the growth of agricultural GNP drops to the average 2.45% a year during the period 1980-85. This results from the slower increase of total cropping areas (as this depends on the index of multiple cropping, a function of irrigation) and from the slower growth of yields. Total grain production falls by 3.5% for 1985. If we also introduce the decline of grain area shares 1% annually until 1985, total grain production declines additionally, and reaches only 265 million tons in 1985.

This is significantly lower than the planned production. (Although one has to take into consideration that our projection refers to net production - i.e. net of seeds and waste - and includes milled rice instead of paddy.)

Our production projection depends on two factors: on area and yields.

Since our area-projections are cautious with respect to the assumption concerning reductions in grain areas, they are most probably not smaller but rather higher than grain areas are to be expected.

Thus the reason of the difference between the planned and projected production might be owing to differences between our projected yields and yields implicitly assumed by the planners.

As the yields projected by the model rely on functions, estimated on historical data base, the question arises, which changes might have been assumed by the planners, resulting in dramatic yield increments, not projected by the econometrically estimated functions? We remind the reader that the explanatory variables of the yield functions are fertilizer (given in nutrient values) and irrigation (in mill.ha irrigated area.)

The projections of the application levels of both input factors can be accepted. For irrigation we took plan numbers, for fertilizer application a trend-function, which might even be viewed at as an optimistic projection. (See also later the discussion of fertilizer inputs in this chapter.)

The most probable changes planners might expect are of qualitative character, such as more careful irrigation practices, better mix and use of fertilizers, forced introductions of high-yield varieties, etc. Although some of these factors could be quantified in principle (such as the fertilizer-mix, using more variables, instead of one; or some variable showing shares of high-yield varieties in total, etc.) this was not possible with the data we had. But the additional problem is that such quantitative changes as better practices, better attitude to work, etc. also change the efficiency of the input factors, and thus the parameters of the functions as well - something we can hardly predict.

This presumed shortcoming of the model clearly shows however what difficulties are associated with the plan-numbers. The expected changes mentioned above are highly dependent on how the new incentive and price system will function and how research and dissemination of its result will develop under the new economic regime.

As the next step, we introduced higher growth rates in grain consumption per capita, than was computed from our data series. If we assume that wheat consumption per capita increases 5% annually between 1978 and 1983 and 2.5% in the next years, our wheat imports reach 9.4 million tons in 1980, 17, and 19 million tons for 1985 and 1990, respectively. As mentioned, our consumption data did not show any trend in rice consumption. This resulted in significant exports in the first run. This amount of "surplus" rice could - and most probably is - swallowed by increased consumption. (As our information is poor on stock policies, we do not consider these in the simulation runs.) According to the model calculations, rice consumption per capita could increase 1% annually until 1983 and 0.5% afterwards, keeping rice exports at present levels.

Coarse grain imports are heavily influenced by our assumptions about changing feeding patterns concerning our commodity 6. According to the development path A (described in Appendix 2), when we assume that although China follows the feeding pattern of other developing countries, but still a significant part both of calories and protein required would be met, as in the past, from sources not included in our commodity list, planned production growth would require 14 million tons import of coarse grains in 1990. Under the rather unrealistic assumption that China would follow a grain-intensive feeding pattern (development path B), coarse grain imports even would reach 40 million tons in 1990. This shows that this way of increasing meat production may not be feasible. But, if development path A would be followed, an annual increase of 5% in the consumption of commodity 6 would be possible until 1983 and 2.5% afterwards. This would probably improve nutritional situation significantly, as the per capita daily calorie intake would reach 3140 calories, while protein intake would reach 87 grams in 1990 (compared to 2351 and 63 in 1970). Average annual growth rate of total agricultural production between 1980-1990 reaches 3.3% in this simulation run.

In the last simulation run we also introduce the assumption of falling investments after 1980. As this run represents the central Chinese development scenario in our modeling system, this will be explained in more detail.

The model has been changed according to the exogenous assumptions i-v listed at the beginning of this chapter. As more realistic with respect to the changed feeding patterns, development path A has been chosen.

As already mentioned, we keep the total land availability constraint in all our runs, although the model allows the introduction of exogenous growth (or reduction) rates.

Agricultural inputs show high increases, except irrigation, since its development was exogenously damped. The production of chemical fertilizer is 12.3 million tons (nutrient value) in 1980, and grows to 16.5 and 20.6 million tons in 1985 and 1990, respectively. As organic fertilizer utilization is already quite high, the rate of increase of its application is smaller than that of chemical fertilizers. In the year 1980 according to our model calculations 22.9 million tons organic fertilizer were applied, and this will reach 28.5 million tons in 1990 (both figures given in nutrient value). The fertilizer imports increase significantly - from 1.9 million tons in 1980 to 4.6 million tons in 1985 and 9.8 million tons in 1990. This might be the result of three factors:

a) our fertilizer application trend increases too rapidly and/or their assymptotic levels, present Japanese fertilizer application rates, are too high with respect to China

b) the utilization rates of organic fertilizer sources are constant in the model, although some improvements on this area might be possible

c) in the production of chemical fertilizers in the model we do not assume imports of huge plants as were made in the late 1970s.

Whichever of these factors be the reason for the large imports, it does indicate that fertilizer still can be a bottleneck in agricultural development.

The number of urban laborers increases from 128 million in 1980 to 209 million in 1990, and the number of workers in rural areas increases from 282 million in 1980 to 304 million in 1990. These results are obtained assuming annual 5% increase in urban jobs and taking the low population estimates of J. Aird (1978).

Mechanization of agriculture (represented by the tractor numbers) increases fast as well, the horsepower of machinery almost doubles in five years. Irrigated area is 54 million hectares in 1985 and 62 million ha in 1990. These input factors enable the following production figures to be realized:

Table 11. Production of grain and cotton million m.t.

	1980*	1983*	1985	1990
wheat	55.2	81.4	54.1	64.2
rice (milled)	93.7†	113.1†	125.0	143.2
coarse grains	84.2	93.0	97.8	105.2
cotton	2.7	4.6	5.03	6.3

* Source: China, Outlook and Situation Report, USDA, ERS, RS-84-8 (1984)

† Conversion factor to milled rice is 0.67

As according to our assumptions the human food consumption increases faster than the trends estimated on the basis of our sample period data, namely they reach the following values: As long as wheat consumption per capita is 41 kg in 1980, this increases to 48.5 and to 53.8 in 1985 and 1990, respectively. For the same years, the figures of rice consumption per capita are 71.4, 74.3 and 76.2 kg. The meat consumption per capita increases by 50% between 1980 and 1985 and by 22% between 1985 and 1990. The increased food grain consumption and the increased feed grain requirements result in the following grain import figures (assuming feeding patterns development path A)

Table 12. Grain imports million m.t.

	1980	1985	1990
Wheat	8.8	15.6	17.0
Rice	-3.1	-0.5	-0.3
Coarse Grain	2.0	6.6	14.0

The nutritional situation develops as follows:

Table 13. Food intake per capita/day

	1980	1985	1990
Calories	2519	2795	3140
Protein (g)	69.2	77.2	87.0

Total consumption (including also nonfood consumption) increases on the average 5.3% annually between 1980 and 1985 and by 4.4% between 1985 and 1990.

Due to the assumed reductions in the investment rate, nonagricultural GNP development is dampened compared to earlier runs, and thus total GNP exhibits the annual average growth rate of 5.6% between 1980 and 1985 and 5.36% in the next five years. The agricultural GNP development doesn't slow down significantly, it declines only 0.03 percent, i.e. from 2.62 percent average annual increase during 1980-1985 to 2.59 percent during 1985-1990. This is somewhat lower than actual plan figures, but it can partly be explained by the simple accounting system of the model, which at present doesn't reflect recent price changes favoring agriculture.

Summarizing we can conclude that clearly the most critical point of future development is - as already discussed, also as model result show - how crop yields can be increased according to plans and how meat production can meet plan numbers, without increased feedgrain imports.

REFERENCES

Aird, J.S. 1978. Population Growth in the People's Republic of China. In U.S. Congress, Economic Committee, Chinese Economy Post-Mao. U.S. Government Printing Office.

Chao, K. 1970. Agricultural Production in Communist China 1949-1965. University of Wisconsin Press.

China: Agriculture 1978. 1979. ER-79-10206. U.S. Government Printing Office

Chinese Agriculture: Development, Production and Trade: Discussion Contributions by N. Landy, J.A. Kilpatrick, and R.F. Dernberger, in Amer. J. Agr. Econ., May, 1980.

Csaki, C. 1979. Second Version of the Hungarian Agricultural Model (HAM-2) WP-79-71. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Dawson, O.L. 1970. Communist China's Agriculture, New York, Praeger.

Etienne, G., ed. 1977. China: Men, Grain and Machines. Agricultural Growth and Prospects. Asian Documentation and Research Center, Studies and Documents, Vol. II., Nos. 3-4, 1977.

Fischer, G. and K. Frohberg. 1980. Simplified National Models—The Condensed Version of the Food and Agriculture Model System of the International Institute for Applied Systems Analysis. WP-80-56. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Ishikawa, S. 1970. A Hypothetical Projection of the Chinese Economy: 1966-81. The Developing Economies, Sept. 1970.

Liu, T.C. and K.C. Yeh. 1973. Chinese and other Asian Economies - A Quantitative Evaluation. American Economic Association, Vol. 63, No. 2, 1973.

Neunteufel, M. 1979. Problem Assessment for China. WP-79-117. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Parikh, K.S. and F. Rabar, editors. Food for All in a Sustainable World: The IIASA Food and Agriculture Program. SR-81-002. Laxenburg, Austria: International Institute for Applied Systems Analysis.

Rawski, Th.G. 1979. Economic Growth and Employment in China. A World Bank Research Publication, Oxford University Press.

Smil, V. 1977. Food Energy in the PRC, Current Scene, June/July 1977.

Stone, B. 1980. Foodgrain Projection Target. Issues and Prospects. International Food Policy Research Institute, Research Report No. 15, 1980.

Surls, F.M. 1980. New Directions in China's Agricultural Imports. Amer. J. Agr. Econ., May, 1980.

Tang, A.M. 1980. Food and Agriculture in China: Trends and Projections 1952-77 and 2000. International Food Policy Research Institute, Research Report No. 15.

Tang, A.M. 1980. Trend, Policy Cycle, and Weather Disturbance in Chinese Agriculture, 1952-70. Amer. J. Agr. Econ., May, 1980.

U.S.D.A. 1977. People's Republic of China. Agricultural Situation. Review of 1976 and Outlook for 1977, Foreign Agricultural Economic Report No. 137.

U.S.D.A. 1984. China, Outlook and Situation Report, RS-84-8

APPENDIX 1

Results of Parameter Estimation

Only equations including parameters estimated from the data base are listed. Numbers in parentheses give the standard error of the parameter above it. R^2 is the corrected determination coefficient. DW is the value of the Durbin-Watson test, in the cases when OLSQ was applied.

$$PGI(t) = \underset{(3.456)}{6.454} + \underset{(0.0239)}{0.1855}\ GNP(t-1) \qquad (2.3)$$

$$R^2 = .86 \quad DW\ 1.8$$

$PFC(i,1,t)$ for *low population* (2.7)

i	a	b
1	-39.68	23.06
2	70.04	
3	31.18	
4	3.507	
5	-8.607	4.291
6	-1.816	1.471
7	1.381	
8	30.04	

$$TRCT(t) = \frac{10.}{1. + 2230.e^{-0.132t}} KA(t-1) \qquad (2.11)$$

(612.) (0.0116) $D.W. = 1.03$

$$PIEQ = \frac{0.9318}{1. + e^{-0.1206t}} KA(t-1) \qquad (2.12)$$

(0.352) (0.043) $D.W. = 1.68$

$$AIR(t) = \underset{(1.39)}{29.8} + \underset{(0.00069)}{0.0084} * (1. - e^{-1/t}) * PIEQ(t) + \underset{(0.203)}{0.595}\, KA(t-1) \qquad (2.13)$$

$$DW = 1.87$$

$$MCI(t) = \underset{(4.655)}{125.9} + \underset{(18.9)}{49.94}\, e^{-\frac{1}{t}\left[\frac{AIR(t)}{TCL(t)}\right]^{0.9032}\left[\frac{TRCT(t)}{TCL(t)}\right]^{0.1}} \qquad (2.19)$$

Area Allocation

$$ARS(i,t) = a_{1i} + a_{2i} ARS(i,t-1) + a_{3i} ARS(i,t-2) + a_{4i} ARS(i,t-3) \qquad (2.21)$$

i	a_1	a_2	a_3	a_4
1	0.05138	1.172	-0.4649	0.0
2	0.0	1.1793	0.6413	-0.8207
3	0.0	1.3764	0.2472	-0.6236
7	0.10525	0.0641	0.0	0.0
8	0.10077	0.3570	0.0	0.0
9	0.00153	0.982	-0.2399	0.0
18	0.01493	0.6993	-0.2464	0.0

$$\ln Y(i,t) = a + b \ln\left[\frac{FT(t)}{TSOWN(t)}\right] + c \ln\left[\frac{AIRR(t)}{TCL(t)}\right] \qquad (2.32)$$

i	a	b	c	R^2	DW
1	1.277	0.2642	0.8216	0.89	1.44
2	1.266	0.3058	0.0	0.84	2.00
3	1.041	0.3161	0.2387	0.91	1.21
18	2.372	0.8510	0.7911	0.89	2.10

$$Y(i,t) = a + b \ln t \qquad (2.33)$$

i	a	b	R^2	DW
7	0.1053	0.0472	0.39	1.72
8	0.2837	0.2606	0.80	2.12
9	28.6	0		

$$PST(t) = \underset{(11.8)}{94.94} + \underset{(0.29)}{3.0168} * FEGR(t-1) \qquad (2.38)$$

$$R^2 = .87 \quad DW = 1.33$$

$$Y(6,t) = \underset{(0.0002)}{0.01243} + \underset{(0.0006)}{0.00741} \ln t \qquad (2.39)$$

$$R^2 = 0.96 \quad DW = 2.12$$

$$PY(4,t) = \underset{(2086.98)}{-5191.31} + \underset{(601.13)}{2453} \ln t \qquad (2.40)$$

$$R^2 = 0.97$$

$$PY(5,t) = \underset{(3517.9)}{-36314.2} + \underset{(1013.3)}{12207.9} \ln t \qquad (2.41)$$

$$R^2 = 0.99$$

$$PY(10,t) = \underset{(0.235)}{0.8486}\, KNA(t-1)^{\underset{(0.163)}{0.656}} - ULAB(t)^{1-0.656} \qquad (2.43)$$

APPENDIX 2

Computation of Modified Feed Requirements

The feeding requirements of developing countries (as computed for the models of FAP's basic linked system) are higher than those of the developed (taken the EEC countries as an example) countries. This means that due to lower efficiency in the developing countries, a higher volume of the feed commodities is required for the production of one unit of commodity 6.

Now one can assume that increasing efficiency helps developing countries to reach present EEC standards in a given period (let us assume 30 years). Accordingly, a hypothetical development path has been computed.

When computing such a development path for China, the following problems arose:

a) China exhibits a very special feeding pattern - in the early 70's between 20 and 25 percent of calories required for the pork production were fed from sources which are not included in our commodity list, i.e. forage products, wastes, etc. (Some 20 percent of the grain feed requirements and almost half of the protein feed requirements have been met by these products.) This means that the requirements which are characteristic for the average of the developing countries are not met, both calorie and protein intake are unrealistically low in the model.
But one can assume that this feeding pattern will change in the future because i) the possibility of calorie intake from outside commodity list products (wastes!) is limited, the more if one considers the rapidly growing animal stocks, and ii) the animal husbandry is being intensified. Accordingly, we assumed that the share of calories consumed from sources outside our model would continuously decrease ; and reach some insignificant level in 30 years, i.e. the feed required from the model commodities is increasing ; approaching the development path of other developing countries (which, as mentioned, approaches present EEC standards).

b) The other problem, when constructing this development path of Chinese feeding patterns, was that according to our model aggregation, we need a feed requirement coefficient of a compound product, including pork, poultry and fish, and the feed requirement has to be given not only in calories and protein, but in given commodities (wheat, rice, coarse grains, etc.). Here we applied the simplifying assumption that i) the proportions of pork, poultry and fish are kept constant and ii) the distribution of the total calorie intake among the commodities fed remains also constant. Using these assumptions, a hypothetical development path of animal feeding has been computed.

At the same time, some yield increase can be expected as well – partly due to technical change, partly due to the more concentrated feeding assumed. (At present, according to the FAO SUA the carcass weight of a pig in China is 55 kg.) This has been introduced in the model, assuming that in the first 8 years of the development period, and then after 15 years again yields would increase by about 10 percent.

When introducing this hypothetical structural change in the production of the meat production (one should stress – production of 'other meat') simulation runs can show effects of present Chinese policies expressing importance of higher animal protein intake of Chinese population. Accordingly it was assumed that the increment of meat production automatically increases meat consumption as well, i.e. the food requirement of meat becomes higher, and thus the "surplus" production will not be exported.

At last we have to mention that this scenario deals only with the category of 'other meat' because a) in the Chinese diet the pork and poultry consumption has high importance compared with bovine meat and b) because cattle is mostly used as draft animals and fed with roughage, thus is less important both for human nutritional and feeding point of view. (Roughage is – at least at present – not included in the FAP model system.)