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ABSTRACT

Introduction

Following accession to the World Trade Organization (WTO), Chinese policymakers have been facing the challenge of defining transition strategies that maintain a socially sustainable level of rural income and employment, meet the needs of rapidly growing urban populations, are environmentally sustainable, and meet international commitments. The study on *"Policy Decision Support for Sustainable Adaptation of China's Agriculture to Globalization (CHINAGRO)"* addresses a range of questions that are at the core of the currently ongoing debate on trade liberalization and globalization. The government of China has adopted "sustainable development" as a major national development strategy and has defined environmental protection as a basic national policy. To achieve this objective for agriculture and forest sector development, there is a need to balance the economic, ecological, and social aspects of these sectors.

An essential tool to support policy analysis is a multi-regional applied general equilibrium (AGE) model including a detailed representation of the Chinese agricultural sector. The analysis requires a clear portrayal of the environmental factors that will shape the future of the food and agricultural sectors. The broader context and the crucial external factors need to be summarized in a harmonized set of assumptions and clearly presented in the form of scenarios. The set of scenarios used in the CHINAGRO modeling and policy analysis covers plausible future trends of all-important environmental, social, economic, and political processes that are not endogenously represented in the model.

CHINAGRO is a joint project implemented by International Institute of Applied System Analysis (IIASA); Center for World Food Studies of Free University (SOW-VU), Amsterdam; Center for Chinese Agricultural Policy (CCAP) of Chinese Academy of Sciences (CAS); Institute of Geographical Sciences and Natural Resource Research (IGSNRR) of CAS; and China Agricultural University. CHINAGRO was co-funded by the European Commission (INCO-DEV ICA-2000-20039) and received support from the Chinese and Dutch Governments, and IIASA.

Objectives

The accession of China to WTO enables the country to open up to international trade and ease the pressure on its food markets where demand for meat and animal feeds has been rising fast following the spectacular economic growth over the past decades. However, this will require significant adaptation in existing farming practices and regional specialization patterns within China, as farmers in many regions will find it difficult to compete with imports. The options for improving productivity per farmer are restricted by limited availability of new arable land, loss of land due to soil degradation and urbanization, and exhaustion of the unused potential for yield increases on the basis of conventional technology.

CHINAGRO has been undertaking a thorough policy analysis in the context of China's integration into the world food system. The study is based on a regionalized model, which

uses statistically tested results and takes into account agro-ecological conditions in a spatial representation at county-level. The project analyses policy needs formulated by the Chinese partners that conform to the main goals of agricultural development in China's Agenda 21: (i) to increase farmers' incomes and provide rural employment (social sustainability); (ii) to narrow regional disparity (political sustainability); (iii) to improve resource use efficiency and product quality (economic sustainability); (iv) to arrest environmental degradation (environmental sustainability); and (v) to maintain an adequate self-reliance in food supply (state security). The model-based analysis explores the potential synergies between these goals.

CHINAGRO has engaged in an informed policy dialogue between institutions in China and the EU on the realization of these targets, based on joint specification and analysis of a range of development and policy scenarios over a 30-year time horizon to 2030. It studies the implications of scenarios and policy options, which are technologically feasible vis-à-vis agro-ecological conditions. It uses a welfare optimization framework to select the preferred policy packages regarding production, consumption and international trade.

The following six points summarize the main objectives of CHINAGRO:

Objective 1: To promote the policy dialogue between the EU and China.

Objective 2: To provide Chinese institutions with modern decision support tools enabling the formulation, simulation and evaluation of alternative policy scenarios.

Objective 3: To carry out model simulations at regional level and to evaluate a range of agricultural and trade policy options with regard to their impact on food self-reliance and trade, rural employment and incomes, regional disparity, resource use and environmental impacts, and sustainable access to food and water.

Objective 4: To explore the international and bilateral (China-EU) dimensions of China's opening up to international trade.

Objective 5: To publicize and disseminate widely through seminars, policy roundtables and use of modern information technology the results and insights obtained from the study.

Objective 6: To train Chinese researchers in the use, maintenance and adaptation of these comprehensive decision support tools.

Key issues and major policy concerns

Recent policy documents and statements by the Central Committee of China's Communist Party, Ministry of Agriculture, and Ministry of Land and Resources point to five issues considered most important for China's sustainable agriculture development:

1. Resource-use efficiency and sustainable development: China has reached the potential limit of almost all its agricultural resources (land, irrigation water, and most fertilizers) in terms of conventional technologies. Further increases of agricultural production will have to rely on improved resource-use efficiency and technology generation through R&D.

2. Increase of farmers' income: The low income of farmers, high cost of agricultural production, large disparity in living standards between urban and rural areas and across regions,

and the prevalence of surplus labour in rural areas are the top obstacles to the enhancement of resource-use efficiency and modern technology application in agriculture.

3. Quality of agricultural products: The lack of quality of agricultural products has been of a great concern to both urban citizens and governments in recent years. The coexistence of periods of over-supply of low quality food products and a shortage of high quality products appeals for a systematic structure adjustment within the agricultural sector.

4. Impact of WTO accession to China's agriculture: production costs of grain, cotton, and some other cash crops have been quite high and their competitiveness in the world market is rather weak. This implies a definite challenge posed by WTO accession to China's agriculture in the short-run.

5. Basic self-sufficiency of grain: This policy goal will be continuously threatened by increasing population, a shrinking farmland stock, difficulty to enforce land protection legislation, environmental deterioration, and weakness in R&D institutions.

A regionalized model-based assessment

There is a clear and widely acknowledged need that China's food problems have to be analyzed within a broader economic framework that incorporates various policy measures, and is capable of testing a wide range of policy alternatives. The analysis should, for instance, not only be confined to agronomic variables and resource assessments, as economic factors will have an increasing impact on the food system. China's labour force is moving from agriculture to the industrial and service sectors, and the typical rural household has become less dependent on agriculture. An increasing number of households will purchase a growing share of their food on the market, especially in the urban-industrial agglomerations of the coastal provinces. Furthermore, complete food self-reliance becomes a lesser priority, as China increasingly generates foreign exchange through industrial exports. A key question is to which extent China should import animal feed or meat, and how the concept of food security can be realized at household rather than state level.

CHINAGRO conducted its analysis within a modelling framework that (i) represents the consumer, producer and government decisions in the various regions, (ii) accounts for transportation costs in the economy, (iii) builds the supply response on spatially explicit assessment of the resource base and its bio-physical characteristics, and (iv) describes agricultural processing and supply of farm inputs.

Due to this set-up, CHINAGRO is a nationwide, regionalized applied general equilibrium (AGE)-model with a great deal of geographical detail. A distinctive feature of the CHINAGRO project is that we have paid due attention to the large spatial and social diversity of the country. We have realized this aim by conducting our analysis at the county level, distinguishing over 2,400 of these administrative units. The model distinguishes eight regional markets, which are linked to each other and to the world market through commodity flows. Hence, this welfare model is rather large, comprising around 50,000 truly endogenous variables including prices, as well as consumption by every consumer group in every region and agricultural production and input demand for every land use type in every county.

The development of a complete and modular calibration procedure for such a large optimization model was, besides the design of an efficient algorithm to solve it, the project's major methodological innovation in welfare modelling. A modular approach to calibration is essential for the future maintenance of this very large model, as it makes it possible to keep database operations fully separate from the modelling work, while improvements in the database are in a transparent way transmitted to the model outcome. Special efforts were made to generate a fully integrated software package for model simulation, from the basic data input, model calibration, dynamic simulation, up to the tabulation and comparison of results, and the display of maps.

As a first set of modelling experiments to provide quantified inputs to the policy dialog, a base scenario and four policy variants were simulated in 2004. The policy variants addressed key concerns of agricultural development: (i) regional impacts of full trade liberalization in agriculture (beyond current agreed levels), (ii) the sensitivity of results with regard to key demand factors, i.e. economic growth and speed of urbanization, (iii) the importance of sustaining long-term technological growth in crop and livestock sectors, and (iv) the impacts of expanded irrigation development.

In the last phase of the project, attention was also given to dissemination activities. In particular, to provide an overview of the basic assessment tool and to share some important findings with a wider policy and scientific audience in China, a "Policy Forum on China's Agriculture Toward 2030" and a "Workshop on Policy Decision Support System for China's Sustainable Agricultural Development" were organized by the CHINAGRO project at the Beijing International Convention Center in January 2005. The Policy Forum targeted the policy makers, the Workshop addressed researchers by providing a background and summary of the CHINAGRO methodology, insights into the data integration and verification process, some details of key scenario elements (namely, land use change, irrigation development, and trade policy), and an overview and sample results of the scenario analyses.

The Policy Forum presented three themes of critical importance to China's policy and agricultural development: (i) China's Grain Security to 2030 (presentation by Jikun Huang, CCAP), (ii) Catering to Future Needs: Challenges for Farmers, Traders and Government (presentation by Michiel A. Keyzer, SOW-VU), and (iii) Sustainable Agricultural Development (presentation by Günther Fischer, IIASA). Presentations were based on simulation results obtained with the CHINAGRO welfare model and key results were summarized in policy briefing notes.

CHINAGRO - Policy Decision Support for Sustainable Adaptation of China's Agriculture to Globalization

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1. Introduction

China's unprecedented economic growth and the gradual liberalization of its trade have led Chinese policymakers to look for new agricultural strategies that can combine sustainable rural development with the necessary adaptation of the agricultural sector to the changing international environment, in particular after the nation's accession to the World Trade Organization (WTO).

While the liberalization of trade will enable China to ease the pressure on its food markets where the trend of a fast growing demand for meat and animal feeds experienced over the past two decades is expected to persist for another two decades or more, it will also require significant adaptation in existing farming practices and regional specialization patterns within China, as farmers will in many areas find it difficult to sustain competition with imports (Huang and Rozelle, 2003c). The options for improving productivity per farmer are restricted by limited availability of new arable land, loss of land due to soil degradation and urbanization, and exhaustion of the potential for yield increases on the basis of conventional technology. Hence, farmers are left with two options: transition to higher value products such as livestock and horticulture, and/or seeking employment outside the sector.

In response to these challenges, the Chinese government has formulated as its major strategic and policy aims: (i) to increase farmers' incomes and to provide remunerative rural employment, and through it maintaining social stability at the local level; (ii) to narrow regional and rural versus urban disparity, to preserve the political stability at the national level; (iii) to improve resource use efficiency and product quality, referred to as the economic sustainability needed to face foreign competition; (iv) to arrest pollution and environmental degradation, required to achieve environmental sustainability; and (v) to maintain an adequate level of self-reliance in food at national level, which is considered an issue of state security.

Even though these strategic goals are by now well recognized and accepted by the public, the ways and means to achieve them is still under extensive debate. China is so large that every region has its own geographical, ecological, and socio-economic specificity. Rather than a nationwide, uniform and undifferentiated set of measures, policy needs a diverse and well adapted package founded on a thorough understanding of the underlying diversity (Fischer and O'Neill, 2004). In this context, the question of the optimal mix between the private and public action needs to be settled. Indeed, in many respects the competitive market is better equipped to address diversity than any other institution. Nonetheless, despite the ongoing trade liberalization process, several institutions are still underdeveloped. With regard to the commodity markets, the institutions related to product grading and consumer protection leave much to be desired, while on factor markets classical imperfections and failures are persisting and bound to require government intervention for many years to come: for land in relation to ownership and land titles; water supply and management; environmental protection and rehabilitation; for labour in relation to safety regulations, workers' health and education; and for capital in relation to property rights, supervision of banking and insurance, only to name a few. Moreover, redistributive measures will surely be needed to contain and reverse a growing income disparity across regions and between rural and urban areas. Finally, the decentralization process itself, whereby autonomy is to be transferred to or left with individuals and local organizations, has become all the more subtle as the generated wealth becomes less evenly distributed among the population. In short, several interventions will be needed that should be planned carefully and duly justified to the public as well as to foreign investors worldwide.

Hence, government agencies, at both national and provincial levels, will have to draft transparent policy documents in which sufficient motivation is provided, in particular to establish that the interventions proposed are necessary, that planned policies are not overly centralized, and that measures are answering to the local needs of every province.

The motivation for engaging in the CHINAGRO project, being reported on here, is that these documents will be more credible when they can rely on science-based decision support tools. In our view and against the background sketched above, these tools should have the capacity to represent the following five aspects of agricultural planning in sufficient detail:

1. constraints of geophysical/natural resource conditions on agriculture production;
2. demand and market forces determining the distribution of agriculture production;
3. spatial spread as well as social and economic diversity of China's population;
4. impacts of policy on regional disparity in farm incomes; and
5. environmental impacts of agriculture.

Literature and previous studies

As these five aspects are well recognized by researchers in and outside China, the literature considering them is extensive and essentially falls in two parts; on one hand the domain of agronomists and economic geographers, describing the geo-physical and natural resource conditions in each region; on the other hand the domain of agricultural economists comparing production costs across regions and determining regional agricultural comparative advantage.

Among the agronomic studies, the study by Zhou (1993) on the theory and practice of China's agricultural regional planning is widely quoted. In Zhou's study, every region was examined according to its climate, temperature, precipitation, soil, landform, and length of crop growing period etc. Based on the assessment of these factors, suggestions were made as to which type of grain and livestock would best match the region's natural environment. With the recent advances in the geographical information system (GIS)-techniques, geographers have been able to elaborate this technique into a comprehensive spatial assessment of the impact of the natural resource constraints on agricultural production, for example by means of the FAO/IIASA Agro-ecological Zones (AEZ) methodology (Fischer et al., 2002a).

This AEZ methodology can be used to identify the geophysical limitations on agricultural production within each region, and to formulate options for more efficient use of the local natural resources. In fact, it provides one of the major inputs into the CHINAGRO welfare model. However, while agriculture production undeniably depends on the available natural resources and environmental conditions, this is only a first important step describing agricultural options and potentials. Regional development planning has to go much further, as agriculture is conducted by farmers, using inputs provided by industry, and delivering to the agro-processing sector and eventually to consumers, domestically and abroad. In short, the full supply chain and its embedding within the economy have to be taken into consideration. In addition, the rapid change currently experienced in this chain has to be accounted for.

Turning to the studies on regional development planning by Chinese agricultural economists, as mentioned with a focus on comparing production costs across regions, we mention Huang et al. (2001) and Xu et al. (2001) who used the Domestic Resource Costs (DRC) method to analyze each province's cost advantage in producing staple grains, economic crops, and main livestock products. This approach has the advantage that it takes into account the differences in prices and input intensities in different regions of, say, labour and fertilizer. However, as it only measures the present situation, it can at best provide a useful guideline on the direction of agricultural restructuring, since any actual restructuring would change regional prices and intensities in response to specific conditions in each region. Any tool adequate to analyzing these factors should be able to account (endogenously) for such changes.

Furthermore, the available studies on regional development do not consider the implications of changes in regional demand resulting from increased income and rural-to-urban migration, both of which significantly affect inter-regional and foreign trade as well as the patterns of production across regions. Indeed, a region with strong cost advantages in production may not be able to realize these advantages fully as high transportation costs, inter-regional trade barriers, and other trade costs can offset all of them. Young (2000) and Hussain (2002) pointed out that transaction costs play an important role in determining the distribution of China's regional agriculture production.

Recently, several partial equilibrium models have been developed that take aspects of these supply, demand and trade interactions into consideration. Huang et al. (2003, 2004) used the CAPSiM regional model, a partial equilibrium model of the agricultural sector, to analyze the impacts of WTO accession on agricultural production, consumption, and farmer income in different provinces across China. The study concluded two diverging trends: on the one hand, trade liberalization will stimulate China's agricultural structure changes in favour of its more competitive sectors (e.g., labour-intensive agricultural products) and may increase the average farming income; on the other hand, trade liberalization will enlarge income disparities among regions. However, the CAPSiM model does not fully consider the resource constraints (such as water and land availability) conditioning production decisions at local level. Xin et al. (2002, 2003) have also developed a regionalized partial equilibrium model, representing China's domestic grain and meat trade. Their model explicitly accounts for transportation costs, but as grain and meat are modelled and simulated independently it cannot handle the interactions between grain and livestock sectors nor does it consider the local resources constraints in each region.

The CHINAGRO models

The importance of considering all of the five critical aspects mentioned earlier and the limitations of available studies inspired the CHINAGRO project to develop and implement models of two kinds: one comprehensive with the county-level as the lowest-level geographical unit, the other commodity-specific and partial but spatially even more explicit.

The comprehensive model is a 17-commodity, 8-region general equilibrium welfare model (see Figure 1). The model comprises 6 income groups per region, with farm supply represented at the level of 2,433 administrative units (virtually all counties), and accommodates for every county outputs of 28 products and 14 land use types in cropping and livestock production. Consumption is depicted at regional level, separately for the urban and the rural population, and domestic trade is inter-regional.

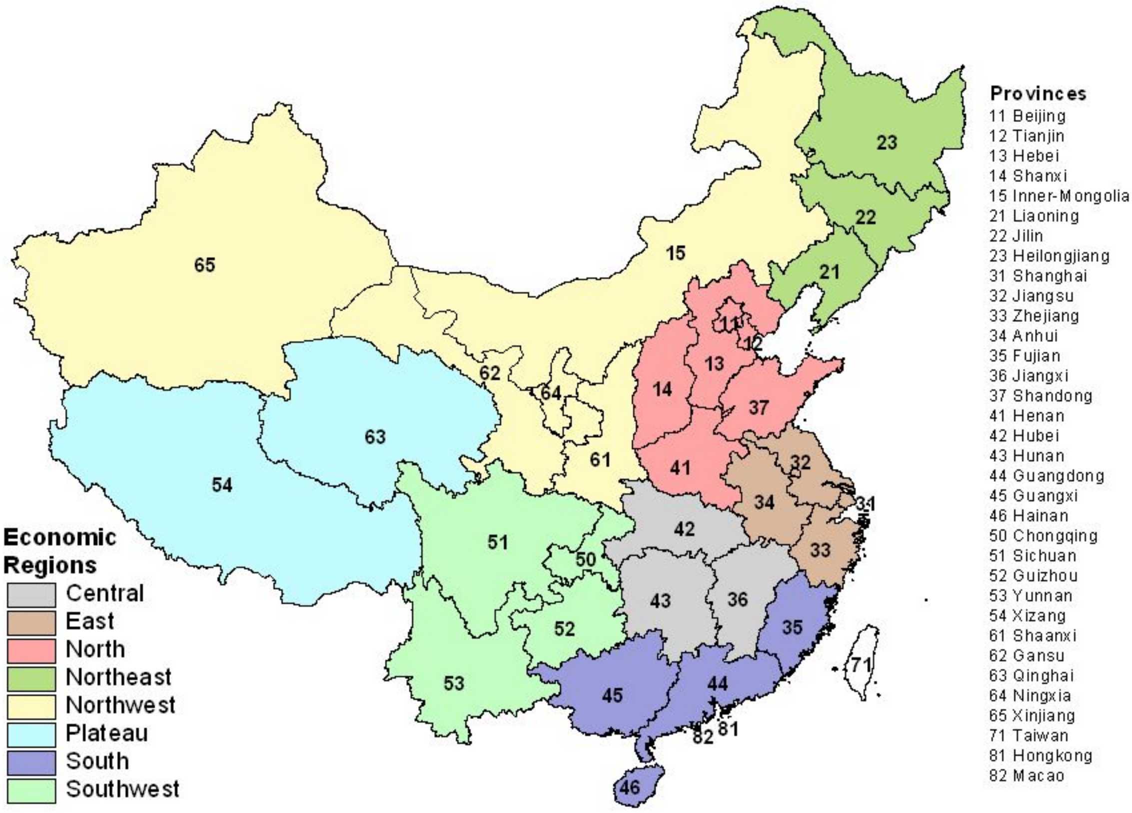
More specifically, the general equilibrium welfare model (Keyzer and van Veen, 2005a,b) is structured as follows. Agricultural supply of each county acts in response to the market prices faced by various farm types in each county, including rain-fed as well as irrigated cropping, and traditional as well as intensified livestock production, separately for ruminants and non-ruminants. The total area for cultivation and the maximal yield potential on each area type is determined on the basis of an agronomic/biophysical assessment using the AEZ model (Fischer et al., 2002a). Labour, fertilizer, and animal feed requirements per unit of output are as well derived on the basis of agronomic information. On the basis of the simulated decisions by all farmers, discharges of manure and fertilizer and resulting environmental pressures have been evaluated at county level as well (Fischer et al., 2005b). Consumers of agricultural products are represented separately for every income group in each region for rural and urban separately, exercising demand dependent on prevailing consumer prices and income available to them. The number of consumers in each group changes under given scenario assumptions with respect to demography and rural-urban migration. With rising income and continued urbanization the demand for luxury foods such as meat comprises a growing share of their food expenditures.

As usual in general equilibrium (see e.g. Ginsburgh and Keyzer, 1997) supply and demand are balanced for all commodities simultaneously through intra-regional, inter-regional and international trade (i.e., three levels of markets are considered), jointly with price adjustment subject to various policy interventions such as tariffs and quotas on international trade. As a result, once market distortions have been eliminated, the model in every particular year generates an optimal allocation of agricultural production among regions, based on comparative advantage, while accounting for transportation costs and respecting regional resource limitations. The model operates on an annual basis, evaluating a solution under given scenario conditions with respect to land availability, demography, economic growth, technological progress, international prices and government policies for selected years over the period 2000-2030. With respect to validation, the welfare model fully replicates for every county and region of China the base-year conditions of 1997, adequately reproduces changes over the period 1997-2003, and provides interpretable results until 2030. It operates within a fully integrated software package that efficiently runs from basic data, via solution algorithms and simulation, to automatic production of detailed county-level maps and tabulation of results.

Run in tandem with the general equilibrium welfare model, the commodity-specific models follow a common specification as a partial equilibrium model with transportation costs. The model is spatially explicit and includes supply, demand and trade flows on a 10-by-10 kilometre grid, totally about 94,000 'market places' represented by these geographic grid cells. The partial equilibrium models provide a transparent geographical representation of supply, demand, and commodity flows between cells, and also of price transmission through the delivery chain, while accounting for transportation costs as well as border measures such as tariffs and quotas, and producer and consumer subsidies. This in particular makes it possible to calculate the density distribution of consumer as well as producer prices within every county and province, and to infer average transport margins from price information, for subsequent use in the comprehensive, yet spatially less detailed, general equilibrium welfare model.

The present report focuses on documenting the findings from the comprehensive model, while the commodity-specific partial equilibrium model is available in the background to analyze spatial aspects in greater detail.

Figure 1. Provinces of China and the eight regions in the CHINAGRO model



Notes on Figure 1: a) Taiwan is not included in the CHINAGRO analysis. b) The map distinguishes eight regions based on their respective geographic, agro-climatic, and demographic features, as well as economic development levels. The regions are subdivided into 31 provinces, representing the actual first level of administrative units in China.

The model-system is put to use in policy analysis as a platform for simulation of scenarios around the major driving forces in China's economy and society, including income growth, changing patterns in consumption and production, urbanization, population growth, technical change, trade liberalization, and environmental factors related to land and water resources. In this summary report, we will present results from five scenarios evaluated with the general equilibrium welfare model: (i) Baseline, (ii) Trade liberalization, (iii) High agricultural R&D investment, (iv) High economic growth, and (v) Enhanced irrigation development.

The remainder of this report proceeds as follows. Section 2 reviews some of the major development trends and their impacts in the Chinese agriculture and rural society, and highlights the key concerns in relation to the fast-rising demand for animal proteins by Chinese consumers. Section 3 looks at important characteristics of China's land, water resources, and environmental risks. Section 4 informs about agro-ecological procedures performed in land productivity assessments. Section 5 introduces the scenarios based on the main external forces that will impact upon Chinese agriculture until 2030. Section 6 gives a bird's eye view of the welfare model specification. Section 7 reports on the model results for the four sets of scenarios. Finally, Section 8 discusses policy implications and concludes with some suggestions for future research. The Appendix A.1 summarizes the model in concise form (based on Keyzer and van Veen, 2005a), A.2 describes the data sets compiled for use in the CHINAGRO models (see also van Veen et al., 2005), and A.3 lists the base-year regional data-set.

2. Major developments since the 1978 reform

The present section reviews some major driving forces affecting China's agricultural economy since 1978 and indicates their projected impact until 2030, the final year of the CHINAGRO scenario simulations.

2.1. Economic growth and regional disparity

China has achieved remarkable economic growth since the start of the reform program in 1978. On average China's gross domestic product (GDP) has grown at more than 9% annually in the past 25 years, an unprecedented record that is the more impressive in view of the country's size. Consequently, per capita incomes have risen significantly in every region, both rural and urban areas. Nonetheless, income disparity increased as well, across regions, between urban and rural and among households in the same region.

It has been widely acknowledged that the successful economic reforms, the country's social and political stability, and the favourable external environment have all contributed to China's remarkable achievements after 1978. They enabled the country to benefit from multiple factors: an abundant and well-disciplined labour force; significant technological progress; fast growing capital investments financed from comparatively high domestic savings (with a savings rate of around 40% in most years); and massive inflows of foreign direct investment (FDI).

The successful initial economic reform of 1978 is to be credited for sparking and igniting the tremendous growth process. Through its efficiency gains, the reform freed the production factors needed in upcoming sectors and created the confidence among the population that was necessary to maintain social and political stability. Next, the success of the reform changed China's image around the world and convinced foreign investors of the numerous opportunities.

Indeed, as China was housing a predominantly rural society, this initial reform started in the agricultural sector. The resulting boost in agricultural efficiency and output significantly improved the health and living conditions of the rural population, and through increased food supply and diversity of the urban population as well. It also freed the agricultural labour for enrolment in education, employment in industry and services, and for (initially regulated) migration from scattered rural settlements, whose households had to rely on home plots, to urban conglomerations where larger factories could be established and benefit from economies of scope and scale.

However, under such fast economic expansion even small differences in performance across sectors or regions have created significant variations in growth rates that, in turn, have led to significant disparities between coastal and inland provinces. The rural to urban income gap has gradually widened since the 1980s, from a gap of less than 2.5 in the middle 1980s to nearly 3.5 recently (NSBC, 2004). While the ratio of per capita farmer income in the richest province to that of the poorest province in 1980 was 2.6, the corresponding number in 2004 has reached 4.3. Within rural areas, an increase in the Gini coefficient from 0.24 in 1980 to 0.35 in 2000 also signals growing income disparity (NSBC, 2004). Migration from the slower to the faster growing segments of the economy, often hindered by political and institutional barriers, became insufficient to close the gaps. In addition, the presently recorded disparities in part have resulted from differences in initial endowments in terms of skilled labour force, natural resources, and location, i.e., accessibility. As the reforms essentially focused on making best use of these endowments, rich regions - the coastal regions in particular - became fast richer while poor regions only became slowly less poor.

Ever since the mid-1990s, this rising disparity has attracted great attention from both policy-makers and the public at large. In response, several regional development and poverty alleviation programs were launched, with some success, as the gap in GDP growth rates between the developed and less developed regions shrank significantly since the mid-1990s, from a gap of about 11 percentage points in the early years to about three percentage points in the late 1990s (Huang *et al*. 2003b, Table 9). During the period 2001-2004, the gap remained below three percentage points. Nonetheless, since the inter-regional migration is significantly less than these GDP growth differences, the discrepancies still generate a widening gap on a per capita basis.

A literature review of the major factors that have driven China’s economic growth in the past two and a half decades suggests that these driving forces are still in effect and that many of them have even been reinforced by the long-lasting growth. On the one hand, the main growth promoting factors include the country’s social and economic stability, the decision to open and to integrate the Chinese economy within the world market, the high domestic saving rates, the abundant labour supply, the strategic emphasis on boosting the economy primarily through science, technology and education, the massive development of rural and urban infrastructure, the favourable external environment, the rapid growth of trade, and the persistent inflow of FDI and foreign technology. Altogether they constitute sound fundamentals for China to maintain its growth momentum and also to improve the quality of its growth. On the other hand, there are a number of factors that may hamper future growth, including China’s demographic transition leading to declining growth rates and ageing of the labour force, increasing wage rates, resource limitations, and the likely decline in domestic saving rates in the long run. The scenarios that were developed in the CHINAGRO study take both groups of factors into account.

2.2. Population dynamics and urbanization

When the People's Republic was founded in 1949, it had a population of 540 million; three decades later the figure had risen to more than 800 million, and in 2005 it had reached 1.3 billion. Indeed, the Chinese population is now young with 39% below the age of 25, and with a fraction of the working age population (i.e., age 15-65) in total population of 70%. This has created a vigorous and mobile labour force that fuels current growth and supports current high levels of savings. Furthermore, despite current low levels of fertility, the youthfulness of the population inevitably leads to growing population numbers for some more years to come. Specifically, the present demography situation exhibits two counteracting trends: while economic growth, urbanization and the associated change in lifestyles may lead to even lower fertility rates, modernization and the opening of society will likely trigger a reconsideration and reversal of the strict one-child policy in family planning.

Also the concentration of its large population in the Eastern part of the country is a basic characteristic of China's current demographic situation. A large part of China's land such as the Gobi Desert, the steep slopes of the Himalayas, the Tibetan plateau, and the vast dry grasslands of the north-central region are nearly uninhabited. Roughly, 1.15 billion people, or about 90% of the population, live on only a little more than 30% of China's land area. Traditionally, the population has been concentrated along the coast and in the fertile alluvial plains of the East, as well as in the Red Basin. The urban agglomerations have developed in these zones as well.

Despite the fact that the urban population is constantly increasing, China can still be considered a predominantly rural society. In 2000, after the rapid increase of the officially defined urban population for more than a decade, still only 36% of the population was classified as urban.[1] This distribution would seem to lag behind the pace of economic and social development as it restrains domestic demand. The most famous headline of "*three nong*" problem, that is, the stagnation of agriculture, farmers' income and rural development, is seen as a consequence of the lag in urbanization and it is appreciated that the agriculture sector cannot resolve these issues by itself, as it needs labour out-migration to improve its productivity per hectare and the income it can generate per worker. The authorities have acknowledged this bottleneck, caused in part by earlier policies, and have proclaimed the promotion of urbanization as a strategic priority of China's economic development in the coming decades.

In fact, given the large pool of underemployed rural labour force and the important disparities in income and living standards, the natural push towards rural-urban migration has been strong for a long time and as the absorption capacity of the cities was limited, migration was kept in check through dedicated institutional arrangements such as the *hukou* registration system, land tenure system and social welfare and security system, all designed to keep the people linked to their place of origin.

Nonetheless, migration was significant and in the past two decades two opposite demographic trends together shaped the population dynamics across regions. On one hand, migration from Western and Central China to the Eastern regions, especially the coastal areas, has contributed several percentage points to the population shares of these regions. On

[1] This research adopts the definition of urban population used in the fifth national population census of 2000. For a detailed comparison across different definitions, see Liu *et al*. (2003).

the other hand, the fertility rates remain higher as one moves from the richer Eastern provinces to the West, and this effect is sufficient to counter the impact of migration. This imbalance will likely be maintained in coming years (Jiang and Zhang, 1998). Furthermore, the coming decades are likely to witness the moving of traditional manufacturing, the heavy industry in particular, from the Eastern regions inward to the Western regions in an effort to curb income disparity and to mitigate pollution in heavily populated areas.

A key question remains: Will cities and towns in China generate sufficient jobs to absorb rural surplus labour in the next two or three decades? There are a number of opportunities and challenges. As to opportunities, China is expected to become a "world factory" with rapid growth of manufacturing enterprises in a global production network, favoured by its cheap labour, maintained social stability, and high rate of domestic savings that will be able to continue attracting foreign investment. In addition, because of its intensive concentration of population along the coast, China can keep good access to the fast growing markets abroad in an era of trade liberalization. Hence, the "world factory" is not expected to stop its expansion very soon. Moreover, this factory has so far been relatively labour-intensive, requiring a large amount of workers with a relatively low level of education and technical skills that migrants from rural areas can provide. At the same time, it also needs significant numbers of supervisory and management staff with good working skills that China can also offer in ample and growing quantity due to its emphasis on boosting the education system. Finally, the service sector in cities and towns is still relatively backward and under-developed. With rising living standards, the demand for services will grow strongly and induce growth. In short, the prospects for continued growth of the cities and improvement of their quality seem promising.

Challenges of economic growth and development also include multiple factors: the sharp decrease in the ability of township and village enterprises (TVEs) to absorb rural labour since the mid-1990s; the serious unemployment problems in some cities occurring as a consequence of the process of economic restructuring and the reform of state-owned enterprises; the inadequacy of urban infrastructure to sustain and accommodate large-scale rural-urban migration; and the lack of social security provision for the migrants to the urban sector. In fact, the absence of adequate social safety nets in urban areas also limits the possibility to restructure the farming systems in rural areas, as the current land tenure system remains essential as an employment safeguard and as an essential source to obtain basic foods from home plots.

In the formulation of the most plausible scenarios for China's urbanization in the coming decades, we take both the expansive and the restrictive factors into consideration, and the eventual net effect of the various trends appears to be that migration is not to significantly affect the population distribution among broad economic regions until 2030.

2.3. Changes in consumption patterns

Consumption trends are the critical drivers of demand for feed and meat, and through it among the decisive factors determining the prospects for China's agricultural economy. As was mentioned before, besides changes in per capita incomes in the rural and urban areas of the various regions and the prevailing demographic trends, the major forces are the changes in consumer preferences and lifestyles associated with migration from rural to urban areas. Meat consumption is much higher in urban areas, while per capita consumption of staples such as rice and wheat is lower in urban areas than in rural households (Huang et al., 2003b).

Traditionally, grains have been of overriding importance in China's food consumption habits, while meat, fishery products, vegetables, and fruits were considered rare luxury items and were often absent from the regular diet. Obviously, the rising living standards have progressively changed this picture. Nowadays, urban residents typically prefer a diverse diet with a greater share of processed foods. All Chinese, rural and urban, now consume more meat and dairy products, so far almost exclusively produced domestically, while per capita grain consumption has levelled off and even declined in some regions. Table 1 shows this trend for meat consumption from respectively 1980 to 1990 and from 1990 to 1999. During both periods per capita consumption of pork increased by more than 30% and per capita consumption of poultry meat by 100%, in both rural and urban areas.

Table 1. Per capita consumption of pork, poultry meat and eggs

	Rural (kg/person/year)			Urban (kg/person/year)		
	1980	1990	1999	1980	1990	1999
Pork	8.5	10.9	13.8	17.4	21.6	29.3
Poultry	0.8	1.4	3.3	2.0	3.8	7.8
Eggs	1.5	3.0	6.3	5.5	8.9	14.8

Source: Ma et al. (2004). Note: consumption estimated in retail weight.

Nonetheless, as China's average food calorie supply per person per day still falls about 10% below the average level of developed countries (about 15% below EU15 level and 20% below United States level), some further rise in per capita calorie consumption can be expected in the future. A comparison of per capita food consumption across some representative countries shows that today's (i.e., average of 1999-2001) food calorie supply of animal products in China is 578 kcal per person compared with 447 in South Korea, 568 kcal in Japan, 1078 kcal in EU15, and 1035 kcal in USA (FAO, http://faostat.fao.org). The average consumption in developed countries is 860 kcal. In addition, it appears that with 35 kcal from fish as compared to 90 kcal in South Korea and 173 kcal in Japan, today's calorie intake from fish is lower in China than in other Asian countries (FAO, http://faostat.fao.org).

Furthermore, a considerable fraction of the population in the poor segments of the income distribution may just have started consuming meat. Combining these factors, the gap indicated by the average figures and the surge in meat consumption by the poor segments of the population, will likely lead to significant increases in demand for meat in the coming two decades.

2.4. Agricultural productivity

Significant improvements in agricultural productivity per worker and per hectare laid the early foundation of China's current economic success (e.g., see Table 2 for past changes in labour input into cropping).

Yet, there still is much room for improvements. For example, while grain yields are in China on average higher than in most developing countries, they are still substantially below the average levels in developed countries. Significant productivity gains could still be achieved through wider adoption of improved HYV seeds; a more balanced application of chemical fertilizers and pesticides; more intensive mechanization; as well as through the increased use of modern inputs such as plastic film and specialized equipment; improved water control for drainage as well as increased irrigation efficiency; and more generally, through improved extension services and related agricultural research.

Table 2. Trends of labour input to cropping agriculture (person-day/ha)

Year	Soybean	Rice	Grains	Cotton	Wheat	Oil crops	Corn
1978	333.0	571.5	429.0	907.5	460.5	442.5	466.5
1985	174.3	328.2	229.2	642.9	218.0	272.3	244.7
1989	170.3	314.6	214.5	607.5	203.3	255.0	251.7
1992	161.0	289.4	201.8	615.0	182.9	234.3	245.4
1995	159.8	285.2	200.7	625.1	190.4	246.5	240.6
1999	118.4	226.7	164.0	453.5	156.9	187.5	192.6

Source: Chinese Rural Statistical Annals (1950-1999), Chinese Agricultural Press, Beijing.

The average annual increase in cereal yields was 1.6% over the period of 1952–1998. For the decades to come, projected yield increases differ widely, ranging between 0.5% and 2.0%, depending on assumptions made with respect to more effective use of land (scale of operations), to the level of investment in research and irrigation, the impacts of salinity and erosion, the opportunity costs of labour and land, and of world market prices (Huang and Rozelle, 1998; World Bank, 1997).

3. Land, water and agro-environmental pressures

3.1 Farmland resources

Turning to agriculture itself, the availability of arable land is generally perceived as a major factor determining the nation's capacity to produce sufficient food for its huge population. Despite its large territory, China is severely limited in its farmland resources that are, moreover, threatened by land degradation and even more so by the expansion of non-agricultural land uses in response to rapid economic growth and urbanization, particularly in the river plains and coastal regions.

According to the land monitoring data of the Ministry of Land and Resources of China (MLR), between 1987 and 2000 the net decrease (after partial compensation by reclamation) of China's farmland amounted to more than 4 million hectares, which translates into an annual loss of 0.3 million ha, due partly to competition from other sectors, and partly to conservation measures. Indeed, of the total farmland lost between 1987 and 2000, 25% was transformed into orchards and fishponds, 22% into built-up lands, and 38% into forestland and grassland for conservation purposes. The remaining 15% were abandoned altogether as the land became unusable due to severe damage by natural hazards. It is widely admitted that these factors will continue to encroach on farmland availability in the coming decades.

Regarding environmental degradation and natural hazards, several provinces of Western China are particularly at risk, as a significant fraction of their cultivated land is located on steep mountainous and hilly slopes. The 1998 Yangtze River flooding and recurring droughts and floods in the Yellow River basin have heightened public awareness of the severity of Western China's ecological degradation and its dire environmental and economic consequences. The loss of key ecosystem services has caused a series of severe environmental and ecological problems downstream. The highly fragile environments have adversely affected the livelihood and welfare of millions of poor farmers and herders, and act as a contra-force on economic development in some of China's poorest provinces. Until recently, conversion of sloped farmland into forest, shrub or grassland has been greatly stimulated through the National Land Conversion Program, initially called the "Grain for Green" Programme. As the ecosystem services and environmental goods provided by the greenlands are not rewarded by the market, government has a crucial role to play to combat environmental degradation and to act as a trustee in natural resource management for the sake of future generations. The current policy is to ensure that by 2010 all farmland on slopes steeper than 25°, will be transformed into forest, shrub or grassland.

While degradation affects large areas of fragile marginal lands, the drop in agricultural production potential is, however, mainly caused by construction activities and peri-urban land conversion, as these tend to take away the best quality farmland. Furthermore, as this loss commonly takes place in the densely populated urban fringes, it has undoubtedly caused a great number of farmers to lose their land. Statistical regression exercises, using data at provincial level, indicate that the annual increase in built-up land is highly and positively correlated with the annual growth rate of provincial GDP and population, and negatively with the degree of use efficiency of built-up land (Lu et al., 2004).

On the accruing side, the factors contributing to farmland increases include land reclamation, farmland consolidation, rehabilitation of abandoned farmland and mining sites, and restructuring of agricultural land use. In the past 50 years, China has experienced a great change in land use. In the 1950s, China faced a serious problem of food shortage. In order to increase food production, China started large-scale land reclamation, particularly in Xinjiang, Heilongjiang, and Inner Mongolia, resulting in a rapid expansion of the farmland area. In the eight years between 1949 and 1957, the farmland area was increased by 14 million ha, mainly in the arid and semi-arid areas. However, due to natural disasters, and problems of sandification and soil salinity, these newly reclaimed lands had to be largely abandoned; up to 1965, a total amount of 8.2 million ha of farmland was lost. (Lu et al, 2004). After 1986, reclamation of farmland slowed considerably (see Table 3).

Table 3. Changes in farmland area in different periods (million ha)

Farmland change	1957–1965	1966–1975	1957–1986	1987–2000
Farmland reclaimed	n.a.	n.a.	25.1	5.1
Farmland lost	n.a.	n.a.	40.7	9.1
Net lost farmland area	8.2	3.9	15.6	4.0

Note: Data for 1987-2000 are from the Ministry of Land and Resources of China. Other data are from Zhang (2000) and Zhang et al. (2001).

According to the Land Management Law and related regulations, farmland converted into construction land should be fully compensated by an equivalent area of reclaimed, consolidated or rehabilitated farmland. However, the feasibility of this requirement is questionable. First, the newly built-up areas will typically not be situated in the same county within a province and hence not fall under the same administrative jurisdiction as the areas where compensation could take place. This creates asymmetric incentives, complicates monitoring, and hinders implementation. Second, the farmers who lost their land to the newly built-up areas tend to be unwilling to migrate to these compensation areas that are often located in more remote and backward areas. Third, the execution of land reclamation, farmland consolidation or rehabilitation projects is very costly. For instance, the mean investment of land rehabilitation and consolidation is estimated by the MLR at 0.122 million

Yuan per ha. According to the MLR data, an annual investment of 33 billion Yuan is required to achieve the planned aim of obtaining a farmland area of 0.25 million ha per year in 2001-2010. Finally, even disregarding the costs, farming might not be economically viable on these usually less productive compensation lands (Li and Wang, 2003). Not surprising in view of these difficulties, a recent land survey suggests that on average compensation takes place for only about two-third of newly built-up land converted from farmland and this only as long as reclaimable land is available within the same province (Lu et al., 2004).

3.2. Irrigation water resources

Next to the availability and quality of farmland itself, availability of water and adequacy of water control are major factors determining the productivity of farmland. Nearly 45% of China's farmland is irrigated, and because of the common practice of intensive multi-cropping on irrigated land, about 54% of all sown area is irrigated[2]. The share of irrigated land varies significantly across regions, due to diverse environmental conditions and availability of water (Figure 2).

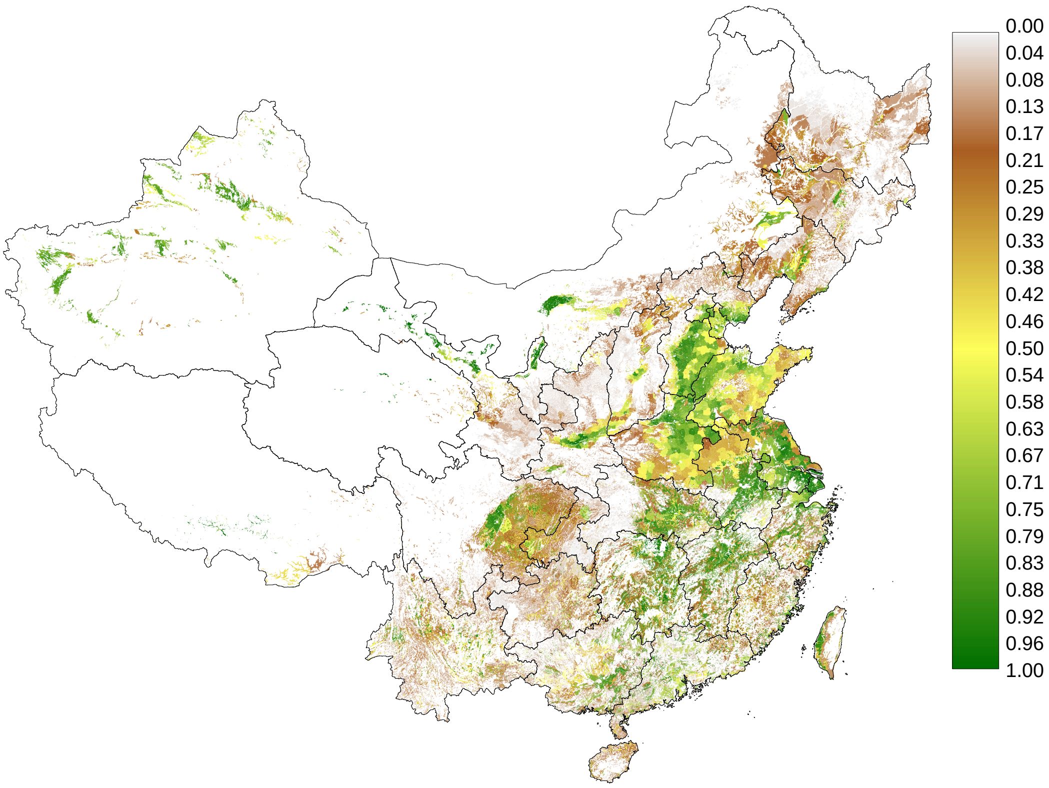


Figure 2. Share of irrigation in cultivated land, 2000.

It ranges from 74% in the Eastern region to 21% in the Northeast. Farming is also more input-intensive on irrigated land. Under similar natural conditions, irrigated land uses 50%

[2] IIASA scientists, in collaboration with researchers from CAU developed an algorithm and parameterization to separate county level statistical data of crop production inputs and outputs in estimates for irrigated and rain-fed land. The algorithm is based on agronomic principles and data compiled by Chinese researchers for a classification of China's territory in terms of cropping system zones. These zones were described in main crop rotations, multiple cropping practices and irrigation conditions. It is estimated that the average multiple-cropping index on rain-fed land was 1.3 compared to 1.8 on irrigated land.

more farm labour and twice as much chemical fertilizer in cropping than rain-fed farmland, and its yield is generally double or more. Using county-level data of year 2000, we have estimated that 72% of total grain output was produced on irrigated land. For rice, the share is well over 90%, for winter wheat over 85%, and for cotton more than 80%, whereas the irrigated share is about 45% for maize, and 30% for soybeans. More intensive cultivation practices on irrigated land are paired with significantly more inputs than for rain-fed land of between 60% (of labour input) to 74% (chemical fertilizer), see Table 4. Consequently the production of the latter major feed grains comes dominantly from rain-fed production.

Table 4. Percentage of cropping inputs and outputs in irrigated land, 2000

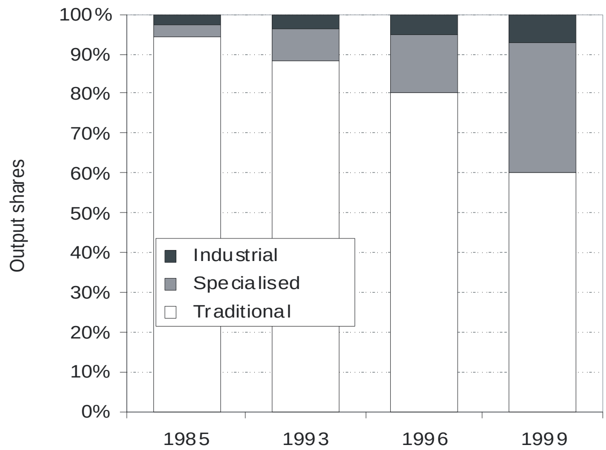
REGION	TCULT	TSOWN	LAB	FERT	RICE	WWHE	MAIZE	COTT
North	53	59	63	77	100	91	64	85
Northeast	18	20	29	32	92	19	19	81
East	75	78	78	88	100	89	51	78
Central	75	77	75	89	99	80	13	73
South	62	67	67	81	98	95	15	2
Southwest	37	39	41	58	98	66	11	31
Plateau	30	32	33	40	n.a.	90	68	n.a.
Northwest	38	42	51	72	100	78	65	93
China	47	55	60	75	99	87	43	82

Note: TCULT = total cultivated land; TSOWN = crop sown area; LAB = agricultural labour in cropping; FERT = chemical fertilizers; RICE = paddy rice; WWHE = winter wheat; SWHE = spring wheat; MAIZE = maize; SORG = sorghum; MILL = millet; SOYB = soybean; COTT = cotton. Values show estimated percentages of total inputs and production in irrigated cropping.

3.3. Intensification of livestock production

China is among the countries with the highest densities of pigs and poultry in the world. It ranks first in pig and poultry production. Pork production is typically classified in one of three production systems: traditional backyard production with 1 to 5 pigs per production unit, specialized farms/households production with 5 to 1000 pigs per unit, and large-scale, industrialized farms with more than 1000 pigs per enterprise.

Figure 3. Share of pork output by production system 1985-1999



Source: Somwaru et al., 2003.

To satisfy the growing meat demand, China has, as many other countries, rapidly adopted intensive peri-urban and urban livestock production systems. Geographical shifts are further determined by changes in infrastructure, availability and economics of feed supplies, and by relative prices for land, labour and capital. This transition has had profound enhancing effects on the industry's performance. As shown in Figure 3, the share of the traditional backyard systems in pork production decreased sharply from 95% in 1985 to about 60% in 1999. This intensification and concentration trend in livestock production will definitely persist, given the foreseeable rise in demand for meat and the limited potential of the traditional, crop residue- and pasture-based production technologies.

The rapid adoption of intensive livestock production systems has far-reaching environmental, economic and social implications, as these systems tend to flourish in areas where feed can be obtained at low cost and where market outlets are favourable. Hence, they concentrate in the vicinity of large cities and harbours, close to consumers, with easy access to (foreign) feed markets, e.g., where food and feed processing industries produce large volumes of by-products useable as feeds. This concentration in turn breaks the traditional link between livestock and cropping activities and through this strongly impacts on the economic geography of the country, hence further justifying the focus of the present CHINAGRO study. Figure 4 presents hotspots of high intensity of confined livestock in 2000.

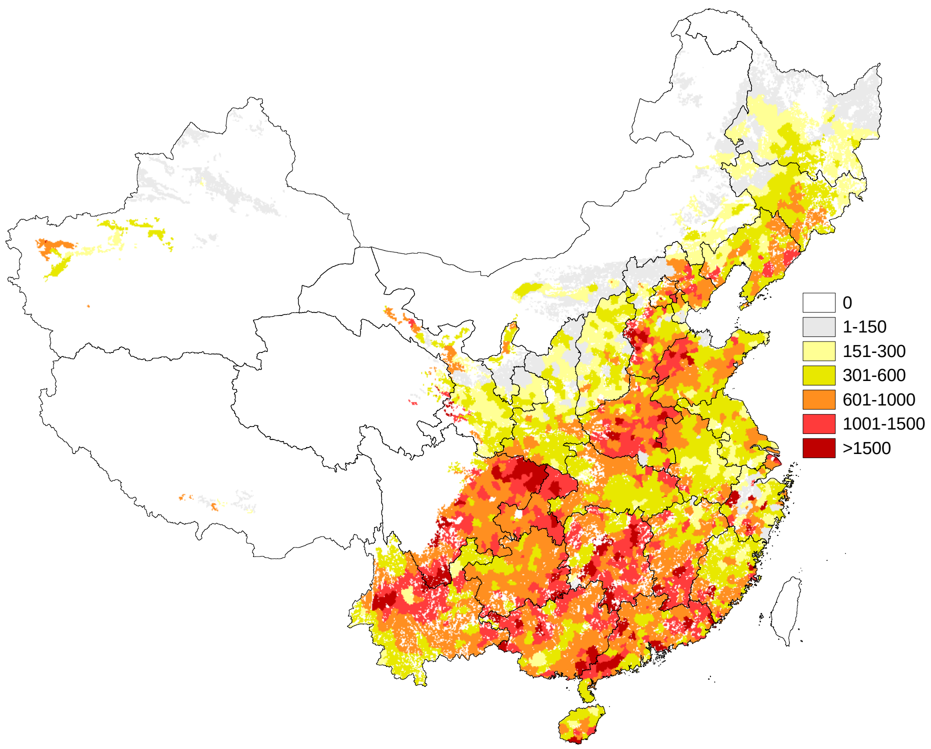


Figure 4. Density of confined livestock (livestock biomass in kg/ha cultivated land), 2000.

Feed Balances

Basic livestock input-output relationships were quantified by region and animal types, distinguishing feed supplies from feed-grains, grassland, crop residues and by-products, as well as household and agricultural wastes. Livestock systems were described in terms of three management regimes: traditional, specialized households, and large-scale commercial production.

In order to understand feed supplies and to estimate future feed requirements, the IIASA team in collaboration with CCAP produced feed balances by region, animal type and feeding mode (traditional, specialized, large-scale).

Results by region, showing the relative importance of different feed sources, are summarized in Figure 5. Figure 6 presents estimated feed diets by animal type. For 1997, we estimate that grassland and pastures have provided about 23% of total feed energy, crop residues and by-products accounted for respectively 14% and 16%. The other (approximately) half of feed requirements was satisfied from primary crop products (35%), mainly grains, as well as household wastes and non-conventional feed sources (12%).

Figure 5. Feed sources (%) by region, 1997

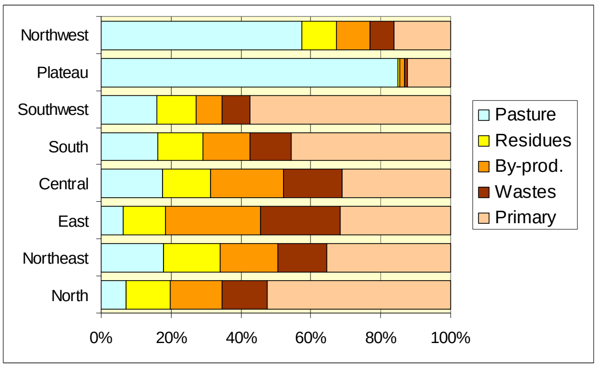
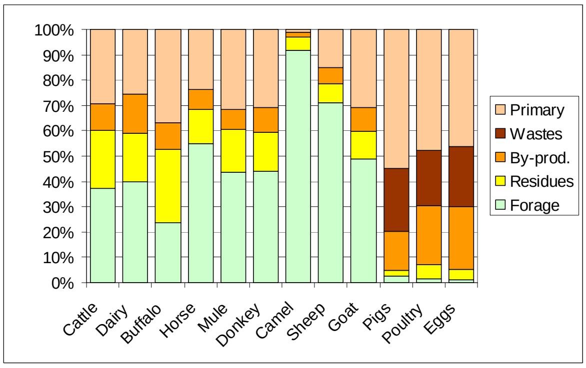


Figure 6. Feed use (%) by animal type, 1997



Environmental pressures and health risks

The choice of options how to expand livestock production determines the vulnerability of socio-economic and environmental systems towards disease risk. The geographical distribution of livestock and intensification levels also determine environmental impacts through nutrient burden from concentrated pig and poultry systems, where insufficient land is available for manure disposal and recycling, causing land and water pollution. Without appropriate treatment this will inevitably increase environmental and human health risks. Environmental impacts are mainly associated with mismanagement of animal excreta leading to significant pollution of surface and groundwater, emissions of manure-related gasses into the atmosphere (methane, nitric and nitrous oxide, etc.), and overload of soils by nutrients.

Problems of environmental pollution and soil loads from intensive livestock production are magnified by concurrent use of chemical fertilizers associated with intensive crop production. China is the world's largest consumer of fertilizers, accounting for about a quarter of total world consumption, with high levels of fertilizer application per hectare of cultivated land. The geographical distribution and intensity of fertilizer use is shown in Figure 7, presenting year 2000 county-level data of nitrogen application per hectare of cultivated and orchard land.

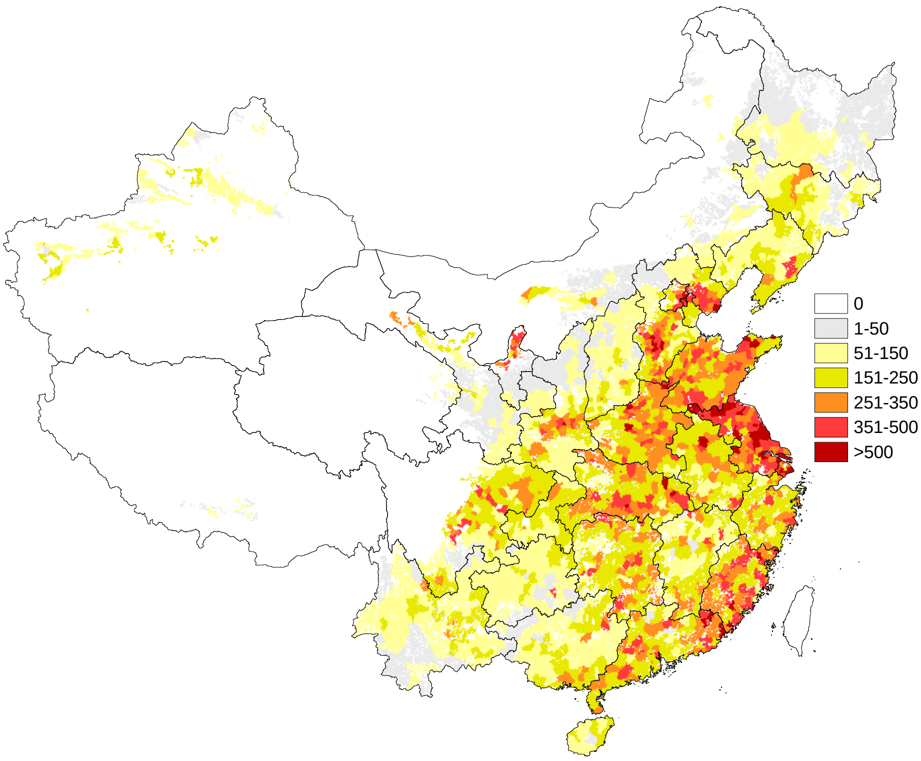


Figure 7. Hot-spots of fertilizer consumption (kg nitrogen/ha cultivated land), 2000.

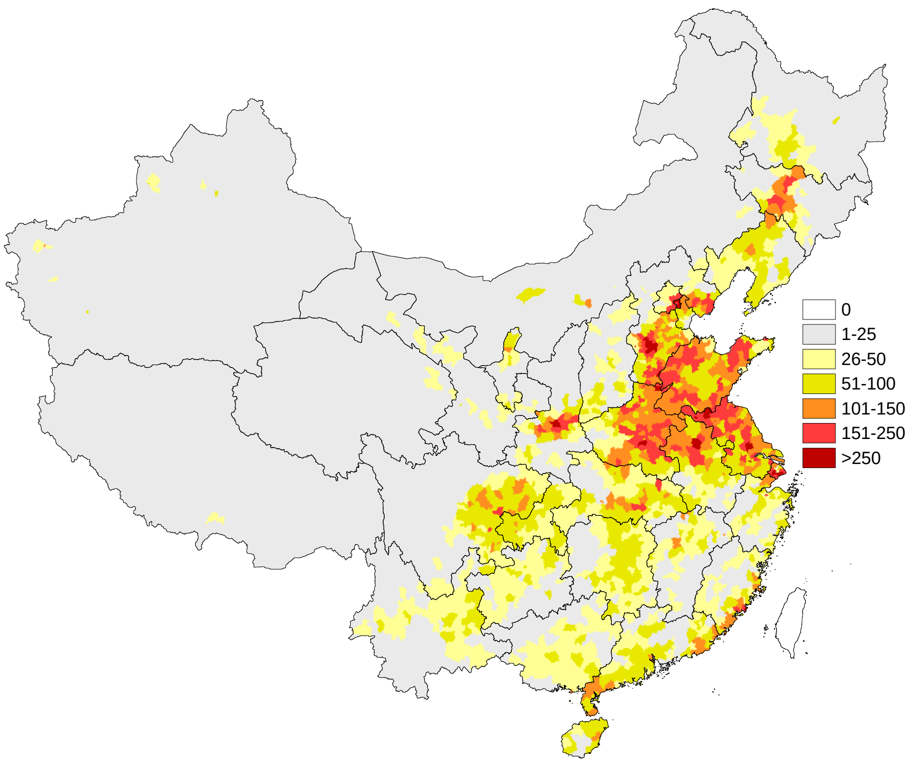


Figure 8. Intensity of nitrogen losses (kg nutrients/ha total land), in 2000.

Detailed nutrient supply and uptake calculations show that nitrogen (N) uptake by crop and fruit production in 2000 amounted on average to 110 kg N per hectare of cultivated and orchard land. Due to different agro-ecological conditions, the province averages vary in the range of 50 kg N per hectare (e.g. Southwest) up to 200 kg N per hectare (e.g. Jiangsu province). In total we estimate that crop production in 2000 has taken up about 16 million tons of nitrogen. This compares to about 24.5 million tons of nitrogen supplied by chemical fertilizer use and an estimated 8.4 million tons of N in livestock manure. Hence, the nitrogen released to the environment amounts to about 20 kg N per hectare of total land. For Jiangsu, Zhejiang, Henan and Hubei this value is well over 100 kg N per hectare implying a very substantial environmental pressure on soils and watercourses (see Figure 8).

4. The AEZ land productivity assessment

The land productivity assessment provides an environmental characterization of land with regard to agricultural uses, to provide a biophysical basis for the estimation of spatially explicit agricultural production relations in the supply component of the CHINAGRO welfare model, and to allow consistent linkage to the project's analysis and modelling of the water sector, in particular irrigation water use.

The choice of applying the agro-ecological zones (AEZ) methodology is based on a number of considerations (Fischer and Sun, 2001): AEZ follows an environmental approach and provides a geographic framework for establishing a spatial inventory and database on land resources and crop/grassland production potential. Data requirements of AEZ are sufficiently limited to enable full coverage of countries as large as China (Xie and Jia, 1994). AEZ makes maximum use of readily available data and provides a comprehensive picture of factors affecting land use and agricultural production.

The AEZ model, developed by FAO and IIASA (Fischer et al., 2002a) uses detailed agronomic-based knowledge to simulate land resources availability and use, farm-level management options, and crop production potentials as a function of climate, soil and terrain conditions. At the same time, it employs detailed spatial biophysical and socio-economic datasets to distribute its computations at fine gridded intervals. It has been validated for use in agricultural resource assessment and applied in many studies, at (sub)national, regional and global scales (e.g., Fischer et al., 2005a; Fischer et al., 2002b); AEZ is one of the main tools used by FAO for analyses of present and future land resources, both regionally and globally (see, e.g., FAO, 2003).

A land-resources inventory is used to assess, for specified management conditions and levels of inputs, the suitability of crops in relation to both rain-fed and irrigated conditions, and to quantify expected attainable production of cropping activities relevant to specific agro-ecological contexts characterizing the study area. The characterization of land resources includes components of climate, soils, landform, and present land cover. Crop modelling and environmental matching procedures are used to identify crop-specific environmental limitations, under various levels of inputs and management conditions.

Results of AEZ include estimation of crop suitability and attainable yields for rain-fed and irrigated conditions, under current and future climate. Quantification of soil moisture status and of crop-specific water deficits, i.e., estimated actual as compared to potential crop evapotranspiration is used to estimate irrigation requirements. As part of the assessment, the AEZ model computes amounts of non-arable and arable land, as a function of environmental constraints. Land is classified as having severe constraints (either too cold, too wet, too steep, or having serious soil quality constraints); moderate, slight, or no constraints to cultivation.

A detailed presentation of all functions of AEZ modelling is beyond the scope of this report (for details see Fischer et al., 2002a). To understand the basic principles of the AEZ approach let us consider a farmer facing the task to evaluate the suitability of a particular land unit for crop production. He/she would take into consideration a whole range of factors, including the quality of the soil, the local climate conditions, and the possibilities of using different types of inputs such as fertilizers, pesticides, machinery, etc. The farmer would also consider various mixes of crops that are possible under the specific conditions of this plot. The AEZ algorithm proceeds in a similar way and incorporates well-established scientific information.

Summary of AEZ methodology

Agro-ecological zoning involves the inventory, characterization and classification of land resources for assessing the potential of agricultural production systems. It includes components of climate, soils and landform, which are critical for the provision of water, energy, nutrients, and physical support to plants[3].

As part of the agro-climatic characterization, a water-balance model is used in each grid-cell, based on monthly historical data of 1958 to 1997, to simulate when, and for how long water is available to sustain crop growth. Soil moisture conditions, together with other climate characteristics (radiation and temperature profiles) are used in a simple crop growth model to calculate potential biomass production and yield over wide geographical areas. This *potential* yield is then combined with several reduction factors, directly or indirectly related to climate (e.g., pests and diseases) and/or soil and terrain conditions. The reduction factors vary according to crop type, the specific environment of a grid-cell, and assumptions about the level of inputs and management. The final results consist of *attainable* crop yields under various production circumstances. To ensure that the results relate to sustainable production, (i) fallow periods are imposed, and (ii) terrain slopes and soils are excluded when too steep and hence susceptible to topsoil erosion.

In its simplest form, the AEZ framework contains three elements: (i) selected agricultural production systems with defined input/output relationships, termed land utilization types (LUT); (ii) geo-referenced land resources data (climate, soil and terrain data); and (iii) procedures for calculating potential yields, matching crop/ LUT environmental requirements (by land unit and grid-cell) with the respective environmental characteristics available in the land resources database.

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[3] The land resources database includes: (i) a climate database from the "Climate Data Bases of the People's Republic of China" (CDIAC, 1998). The data has been interpolated to provide a gridded climatic database with 5 km resolution; (ii) a digital soil map of China, also at 5 km resolution, containing soils information according to the revised FAO 1990 legend (FAO/UNESCO/ISRIC, 1990) for about 2700 soil mapping units. The digital map was compiled by the Institute of Soil Science, Academia Sinica in Nanjing (FAO/Academia Sinica Nanjing, 1995) and published in FAO/IIASA (1999); (iii) terrain slope distributions for 5 km grid cells have been derived from the 30 arc second resolution GTOPO 30 global DEM (EROS Data Center, 1998); (iv) current land use has been derived from digital information at 1 km grid cell resolution (Liu, 1996); (v) a farming system zonation with current crop and cropping pattern information; and (vi) a county database including county-wise socio-economic and demographic data, and agricultural statistics.

For each crop type and grid-cell, the procedures determine the optimum starting and ending dates of each crop growth cycle to ensure best possible crop yields for both rain-fed and irrigated conditions. This also guarantees maximum adaptation in simulations with year-by-year historical weather conditions, or under climate distortions when analyzing different climate change scenarios. Implementing the AEZ procedures in this way simulates ‘smart’ adaptive farmers.

Exploitation of climatic potentials for agriculture and maintenance of land productivity depends mostly on soil fertility and management of soils, as captured by the AEZ agro-edaphic suitability classification. FAO and other organizations have used the soil-rating scheme intensively at various scales, and in numerous countries and regions. It has passed through several international expert consultations and constitutes the most recent consolidation of expert knowledge, providing suitability classifications for each soil unit and for individual crops at defined levels of inputs and management circumstances. Finally, the terrain slope suitability classification accounts for risks of erosion through defining permissible slopes for cultivation of various crop/LUTs by setting upper slope limits. It also calculates likely yield reduction (due to losses of fertilizer and fertile topsoil) for slopes within the permissible range and takes into consideration farming practices, from manual cultivation to fully mechanized cultivation.

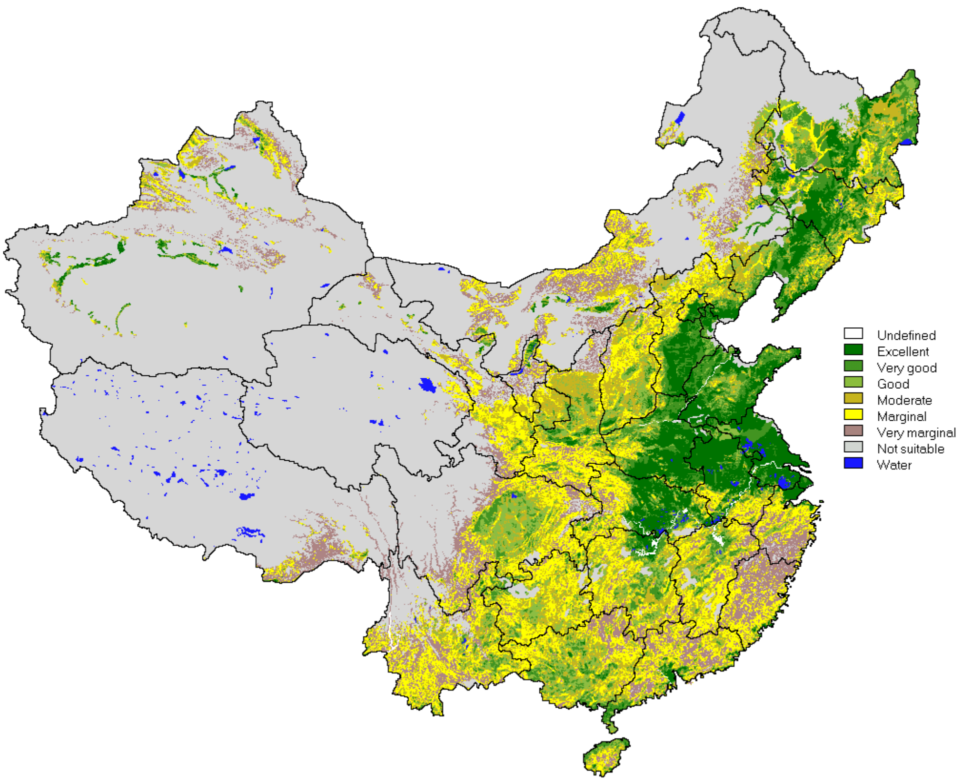


Figure 9. Land suitability for rain-fed and irrigated cereal production

Results of the crop suitability analysis[4] have been aggregated over crops and summarized in tabular and map form. For instance, suitability of each 5x5 km grid-cell can be represented by a suitability index, reflecting the level of suitability of the suitable part of each grid-cell, and

[4] Suitability assessment procedures for grassland and natural pastures include enhanced Net Primary Productivity (NPP) calculation procedures (Zhang X. and Zhou G., 1995) for arid zones.

the percentage suitable in that particular grid-cell. Regression analysis has confirmed that for China, the suitability index is highly correlated with the observed distribution and intensity of farmland. The results of general crop suitability for China, assuming an intermediate level of management and input conditions, are shown in Figure 9.

Multiple cropping

Another important characteristic of China's agriculture is the complexity and widespread practice of multiple cropping. The capability to grow two or even three crops within one year foremost depends on the thermal regime of a location. When practiced under rain-fed conditions, soil moisture can be limiting as well. The AEZ procedures include an assessment of suitability for multiple cropping. A classification of China's cultivated land in terms of multiple cropping potential applicable to irrigation conditions is presented in Figure 10.

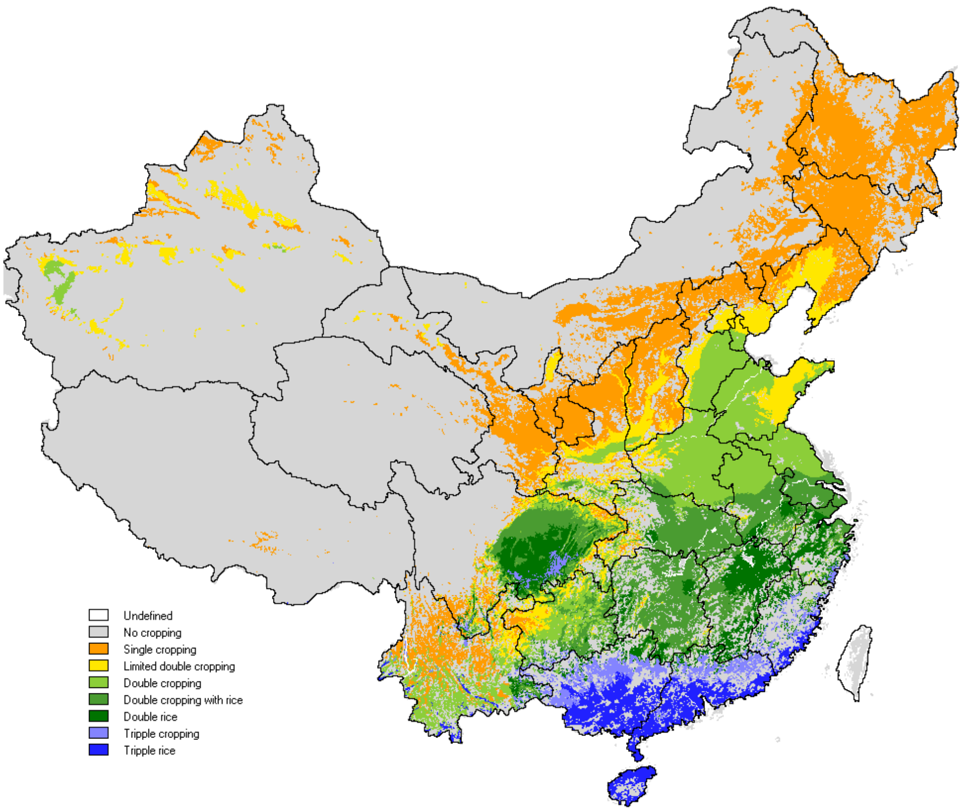


Figure 10. Thermal suitability of China's cropland for multiple cropping

In *Zone 1* (Single cropping), thermal conditions allow for only one crop to be grown per year. The potential yields are determined by the highest simulated yield among all suitable cereal crop types under irrigated and rain-fed conditions, respectively. In *Zone 2* (Limited double cropping), temperature profiles permit cultivation of two short-cycle crops or relay cropping systems. Examples are wheat and millet grown in sequence, or wheat/maize relay crops. Yields are calculated separately for crops adapted to cool and to moderately warm or warm conditions. Potential yields at county level are constructed from these pools according to the observed multi-cropping index (MCI). *Zone 3* (Double cropping) is a typical double-cropping zone with wheat or barley grown as winter crop (including a dormancy period) and crops such as maize, soybean or sweet potato grown in the warm season. Potential annual yields are constructed from these two pools.

Zone 4 has double cropping similar to the previous zone, except that the main summer crops such as rice or cotton demand more heat. *Zone 5* (Double rice) is generally found south of the Yangtze, and permits limited triple cropping consisting of two rice crops and, for instance, green manure. The annual temperature profile is usually insufficient for growing three full crops. When the observed MCI does not exceed 2, the combination of the best suitable crops during the cooler and warmer seasons of the year defines the potential annual yield. The more the observed MCI exceeds 2, the less applicable are crop types with long growth cycles because of the time limitations. When the MCI approaches 3, only crop types requiring 120 days or less are considered when calculating annual potential output. *Zone 6* (Triple cropping) occurs in southern China and allows three sequential crops to be grown. A typical example is the cropping system with one crop of winter wheat and two rice crops grown in spring to autumn. In this case, only short cycle crops can be considered. Finally, *Zone 7* delineates the most southern part of China where tropical conditions prevail, and allows three crops to grow that are well adapted to warm conditions, e.g., rice. In our calculation, this condition is satisfied when the growing season is year-round and annual accumulated temperature (above 10ºC) exceeds 7000 degree-days. Only crop types requiring less than 120 days until harvest are considered when the MCI exceeds 3.

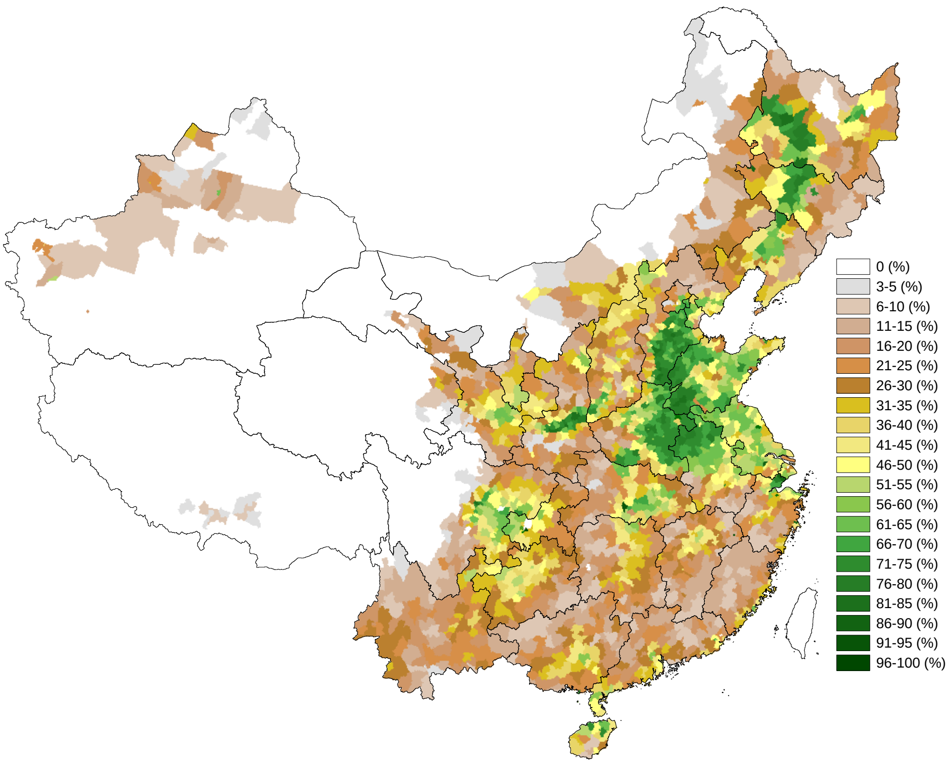


Figure 11. Intensity of cultivated and orchard land (% of total land in county) in 2000.

County crop production potential

To arrive at the potential yields/production for use in the CHINAGRO welfare model supply component, a suitable aggregation had to be performed, in three steps:

- classification of each 5x5 km grid-cell of the land resources inventory for China into one of seven major multiple cropping zones (see Figure 10),
- classification of cereal crop types into eight crop groups according to crop cycle length and thermal crop requirements, and
- aggregation of results at 5x5 km grid-cells to county administrative units according to spatial land use information on the geographical distribution of cultivated land and use of irrigation (see Figure 11 for distribution of cultivated land and Figure 2 for intensity of irrigation in cultivated land)[5].

The calculations and aggregations were performed separately for rain-fed and irrigated conditions and a database was produced characterizing the agronomic/biophysical (rain-fed and irrigated) potential of each county. These variables play a key role in the county-level supply component of the CHINAGRO welfare model.

5. Scenario design

As discussed in Sections 1 to 4, the major driving forces shaping the future dynamics of China's food and agricultural sector include: (i) increasing household incomes, (ii) further urbanization, (iii) changing consumer demand patterns as a consequence of (i) and (ii) as well as of globalization, (iv) substantial conversion of land for non-agricultural as well as ecological reasons; and (v) land scarcity, land degradation, water scarcity, and ground and surface water pollution that could also severely affect drinking water quality in some regions.

As an obvious consequence of this multiplicity of factors, the quantitative analysis of China's future role in the world food and trade system required the specification of integrated policy and development scenarios, which were used to set the policy levers in the policy simulations with the CHINAGRO welfare model and to prescribe alternative future trajectories for variables, which constitute exogenous inputs to the model simulation experiments.

The developments sketched in the previous sections raise numerous questions. The following are among the most prominent and critical ones:

- Will the increasing demand for meat under continued rural to urban migration cause China to become a major importer of feed grains?
- Will the shift to luxury food, jointly with technological progress, generate a surplus of rice production, to be disposed of on the world market, or will the ongoing shift in cropping patterns towards fruits and vegetables and the loss of farmland to urbanization offset this effect?
- Will farmers in poorer regions of China be able to increase their incomes by supplying the growing domestic livestock and/or feed grain market, or will intensive large-scale production units and foreign exporters be better placed particularly for deliveries to the coastal regions?
- How can the North, a region with still large potential for feed grain production, overcome the disadvantage of its long distance from the livestock industry, and how

[5] The geographical data sets of shares of cultivated land in each 5 x 5 km grid cell were obtained through application of a formal down-scaling procedure (Fischer et al., 2005c), which ensures that land-cover distribution (Liu, 1996) and statistical data from MLR are combined in a consistent way.

can the irrigation requirements in this semi-arid and generally water-deficit region be met to succeed as a major supplier of feed and/or livestock products?

- How will WTO accession and trade liberalization affect specific commodities with strong competition from outside, such as sugar, protein feeds and feed grains? How will it impact on the income distribution across regions and between the rural and urban segments of the population?
- To which extent are the projected developments in livestock intensities and irrigation requirements environmentally sustainable in the longer term? If not, what type of measures should be taken to achieve sustainability?

The CHINAGRO-project has been a venture to address these questions by means of a set of simulation models, in order to project the joint impact of the specified trends on China's food and agricultural supply, demand and prices for every region, and for every county with respect to agricultural production and resource use. Specifically, the simulation models provide a systematic and rigorous framework to project agricultural development under different scenarios varying assumptions with respect to policies and regulations as well as the external environment in which the agricultural sector will operate.

The scenarios establish plausible future trends for all-important socio-economic, political, and environmental processes that are (and have to be) treated as given in the CHINAGRO welfare model, which is confined to the description of: (a) supply response by farmers under their prevailing technology and natural resource endowments by county; (b) the behaviour of consumers by region and income group, separately for rural and urban; (c) the balancing on the regional markets of supply and demand, with associated trade between regions and with foreign markets.

Scenario formulation involved consideration of a range of policies and institutional settings. The main tasks related: to describing the institutional context and orientation within which the land use system and agricultural sector will operate; to define the extent to which development of land and water resources will be given priority in investment decisions; to explore the role of R&D policies and expected impacts; to specify the key factors outside agriculture that induce regional economic development; and to determine the integration level of China's agriculture into the international trade system.

A number of factors and policies were reviewed and quantified for implementation in the various scenario experiments for model simulation. The main themes, for which current policies and alternative future trends needed to be assessed, include:

- Land use change dynamics and level of protection of farmland,
- Urbanisation and migration of rural labour,
- Regional development priorities,
- Institutional features of agricultural markets; kind and level of policy interventions and restrictions; trade policy; alternative levels and definitions of food self-reliance. Also, the China-WTO and other agreements were analysed in detail and translated into scenario assumptions and parameters,
- Water sector developments, especially with regard to irrigation practices, distribution and pricing mechanisms, as well as inter-basin water transfers, and
- Trends of agricultural technological change, and level of R&D spending in agriculture.

In addition to the above themes, which heavily depend on government policies, three additional topics were included in the scenario formulation, which frame the changing context within which agriculture operates but which are under less direct influence of government policies:

- Population growth and regional distribution,
- Income growth and life-style changes, and
- Climate change impacts.

In view of China's great socio-economic, geographic and ecological diversity, these forces impact very differently in the various parts of the country and they follow different temporal patterns. Therefore, the CHINAGRO scenarios are designed by province and region, leading to assumptions for scenario formulations at the county level as far as agriculture is concerned and separately for rural and urban areas as far as consumption and trade are concerned. Each scenario embodies key assumptions on the shifters of demand, supply and external economy.

Scenario simulations with the CHINAGRO model cover the period 1997-2030. In consultation with all partners, the main exogenous elements of the model scenario specification for the period 2003-2030 were identified. Decisions were made about the design of the scenario input file, and its transmission from data set to model software (for details of data files used in the CHINAGRO welfare model see Appendix 2). Then, a process of intensive testing and readjusting followed in order to arrive at a plausible and broadly accepted (among partners) simulation of a reference scenario (*BASELINE*). Finally, alternative scenarios were specified, testing certain deviations from the *BASELINE* scenario.

All scenario simulations start from a common assessment of the outcomes in reference year 1997, and in 2003, the latest year for which data were available. Policy variants are evaluated from there onwards, for the years 2010, 2020, and 2030, as modifications of the *BASELINE* scenario.

As a first set of simulation experiments, to provide substantive inputs to the CHINAGRO policy exercises, four policy variants to the *BASELINE* scenario were simulated. The policy variants addressed four key concerns of agricultural development:

- Full liberalization (*LIBERAL*) scenario: assumes complete removal of border protection of agricultural commodities beyond currently planned levels (50 percent elimination of border protection in 2010, full elimination from 2020 onwards);
- High economic growth (*HIGHGROW*) scenario: assumes a high economic growth path in the non-agricultural sectors, at the upper end of the range of plausible economic projections selected for CHINAGRO (Huang et al., 2003d), combined with a faster rural-urban migration and hence a higher urbanization level than *BASELINE*;
- High agricultural R&D investment (*TECHPRO*) scenario: assumes higher (neutral) output increasing technical progress for crops (0.5% additional technical progress annually) and livestock (0.2% additional technical progress annually); and
- Enhanced irrigation development (*IRRIGUP*) scenario: assumes same changes of total cultivated land as *BASELINE*, i.e. from 128.2 million ha in 2000 to 117.6 million ha in 2030, but expanded irrigation development (an additional 10% of effectively irrigated land compared to *BASELINE* scenario). The additional irrigated land was regionally distributed according to the analysis and specification of experts from China Agricultural University (Chen et al., 2005). Rain-fed cultivated land was reduced accordingly.

The results of these five scenario simulation variants (*BASELINE* plus four policy variants) provided the quantification of policy impacts discussed in a CHINAGRO Policy Forum and Workshop (see Section 8). A summary of some key scenario indicators, at the aggregate national level, is presented in Table 5.

Table 5. Some key parameters underpinning the CHINAGRO scenarios

	Scenarios			
Major Driving Forces	BASELINE	LIBERAL	HIGHGROW	TECHPRO
GDP (Index)				
2000	100	100	100	100
2020	370	370	410	370
2030	610	610	770	610
Population (million)				
2000	1275	1275	1275	1275
2020	1429	1429	1433	1429
2030	1459	1459	1468	1459
Urbanization (%)				
2000	36	36	36	36
2020	50	50	55	50
2030	58	58	64	58
Arable land (mill. ha)[6]				
2000	128.2	128.2	128.2	128.2
2020	119.4	119.4	118.4	119.4
2030	116.6	116.6	114.8	116.6
Livestock units (Index)				
2000	100	100	100	100
2020	122	122	125	122
2030	129	129	133	129
Productivity growth (% p.a.)				
Crops 2000-2030	1.2	1.2	1.45	1.7
Livestock 2000-2030	1.3	1.3	1.4	1.5

Note: In terms of indicators shown in Table 5, scenario *IRRGUP* is identical to *BASELINE*.

5.1. Baseline scenario (BASELINE)

The assumptions under the *BASELINE* scenario represent future trends for population development, pace of urbanization, income growth, level of trade liberalization, technology changes, land and water available for agricultural use, and expansion of livestock capacity. In part, e.g. for land and livestock capacity, these trends have been determined with separate simulation models, using income growth, population change and urbanization as the major drivers, in a way that seemed most plausible and probable, usually taking model parameters from the middle of a range of scenario assumptions used for sensitivity analysis.

[6] In addition to arable farm land there is about 10.5 million hectares of land used for orchards in 2000, projected to increase to 12.3.

Demographic change and urbanization

A total of five regional population projections were developed in CHINAGRO (Toth et al., 2003), clustering assumptions in a scenario matrix along two groups of attributes: fertility, mortality, educational achievements, and migration on the one hand, and convergence of fertility levels in educational categories and in the urban/rural regions, on the other. For the national total, the population projections start from a level of 1.20 billion in 1995 and reach 1.27 billion in 2000. There is relatively little variation among projections of total population for year 2010 (about 1.36 billion) and year 2020 (1.41-1.43 billion), becoming somewhat wider thereafter; in year 2030 a projected range of 1.43-1.47 billion people is estimated. Extending beyond 2030, in the low and central fertility population projections the maximum population level is respectively reached around 2035 and 2040, whereas the high fertility projection still shows increasing numbers in year 2050. In a situation where fertility is below replacement level, the future population numbers are dominated by the population momentum, i.e., the age/sex structure of the year 2000 population largely determines mid-term future population levels.

In contrast to rapid industrialization attained primarily due to an abundant labour force, China's urbanization has proceeded rather slowly during 1980 – 2000 due to urban-rural segmenting institutional regulations. Now the process of urbanization is being considered as a mighty potential for economic development and it is anticipated that urbanization will accelerate in the next decades. Starting from 36% urban population estimated by the 5th Census for year 2000, and based on different assumptions on the prospects of China's market-orientated institutional reforms, we project that China's urbanization level will reach 42 to 45% in 2010, some 48 to 55% in 2020, and will fall in the range of 54 to 64% in 2030.

In the *BASELINE* scenario, the population increases from 1.27 billion in 2000 to 1.43 billion in 2020, and to 1.46 billion in 2030. The share of urban population rises from 36% in 2000 to 50% in 2020 and 58% in 2030. A summary of population development and urbanization levels in the BASELINE scenario by region is listed in Table 6.

Table 6. Population development and urbanization, by region, *BASELINE* scenario

Region	2000		2020		2030	
	Total (million)	Urban (%)	Total (million)	Urban (%)	Total (million)	Urban (%)
North	311	33	343	48	348	55
Northeast	106	51	110	62	106	67
East	198	42	214	57	215	64
Central	167	31	175	45	172	53
South	130	50	191	63	221	69
Southwest	243	26	255	39	250	47
Plateau	7.8	26	9.9	38	11	46
Northwest	111	32	130	45	135	52
CHINA	1,275	36	1,429	50	1,459	58

Source: Toth *et al*. (2003) and Liu *et al*. (2003).

Figure 12. Rural population by age class

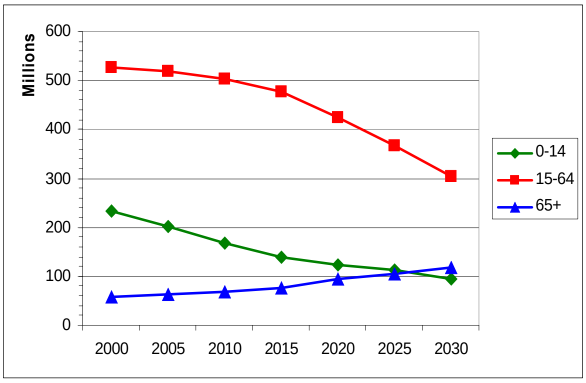
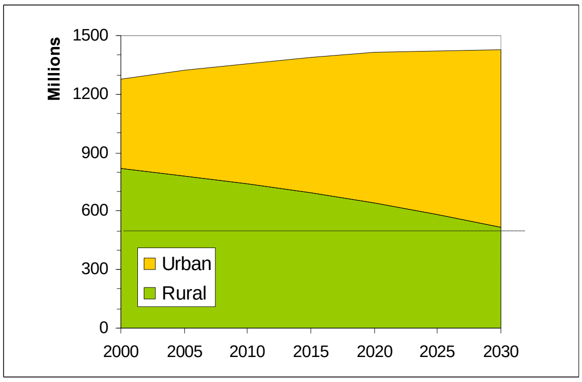


Figure 13. Population change in *BASELINE*



One important aspect of all population projections used in CHINAGRO is that the rural population in China is significantly declining (see Figure 13), both in relative as well as in absolute terms. This suggests that land consolidation and economies of scale will likely contribute to productivity increases in agriculture. On the other hand, the projections indicate that the inevitable process of population ageing will be even faster in rural areas than average (see Figure 12), due to the fact that most of the rural to urban migrants are from the most active, younger segment of the labour force.

Economic growth

Remarkable progress has been achieved in the economic performance after China started its reform in the late 1970s. Annual average growth rates of gross domestic product (GDP) reached about 10% in the past two decades.

The rapid growth has been accompanied by sharp structural changes in the economy. While agriculture accounted for more than 30% of GDP prior to the economic reforms in 1979, by 2000 the share of agriculture had fallen to 16%. The share of service sectors in the national GDP increased from 13% in 1970 to 21% in 1980 and 33% in 2000. The share of industry remained relatively stable at around 45-50% (Huang et al., 2003d).

In the Eleventh Five Year Plan (2001-2005) and the strategy for long-term economic development, China set ambitious goals to move the nation to a "welfare society" (*Xaiokun Shehui*) in the next 20 years: double GDP in each 10 years; a smooth transformation of the economy from transition to development, from rural to urban, and from agriculture to industry and services; sustainable management of the environment; and other social and political targets (Jiang Zeming, 2002).

High growth is also likely to continue in the coming decades though the growth rates might be reduced gradually over time. Accounting for uncertainty in external factors and China's ability to manage its economy, three alternative growth scenarios were formulated to set the macroeconomic context within which agriculture will operate (Huang et al., 2003d).

The *BASELINE* scenario assumes that by 2020 China's GDP will grow to a level of 3.7 times its size in 2000, and by 2030 total GDP would reach 6.1 times its size in 2000. This amounts to an average annual GDP growth rate of 7.7% over the period 2001-2010, 6.2% in the 2010s, and 4.9% in the 2020s (see Table 7).

Table 7. Average annual GDP growth (%), by region, *BASELINE* scenario

Region	2001-2005	2006-2010	2011-2015	2016-2020	2021-2025	2026-2030
North	8.2	7.4	6.6	5.9	5.2	4.5
Northeast	6.7	6.1	5.6	5	4.4	3.9
East	8.7	7.8	7.0	6.2	5.5	4.8
Central	7.9	7.0	6.3	5.5	4.8	4.2
South	9.4	8.5	7.7	6.9	6.2	5.6
Southwest	6.7	6.1	5.6	5.0	4.5	4.0
Plateau	7.6	7.0	6.5	5.9	5.4	4.9
Northwest	7.3	6.6	6.1	5.6	5.0	4.5
CHINA	8.2	7.3	6.6	5.9	5.2	4.6

Source: Huang *et al*., 2003d.

Farmland resources

Using the scenarios of population growth, urbanization, economic growth and investment, the changes of cultivated land are projected based on Lu et al. (2003). In the *BASELINE* scenario the extents of cultivated land decrease from 130 million hectares at the end of 1996 to 119 million hectares in 2020 and to 116 million hectares in 2030, which implies a cumulative net reduction rate of about 10% over 30 years. There is only a small increase in the aggregate national irrigation share, from 45% in 1996 to 48% in 2030, but due to land conversion there is still a small decrease of total irrigated areas (see Table 8).

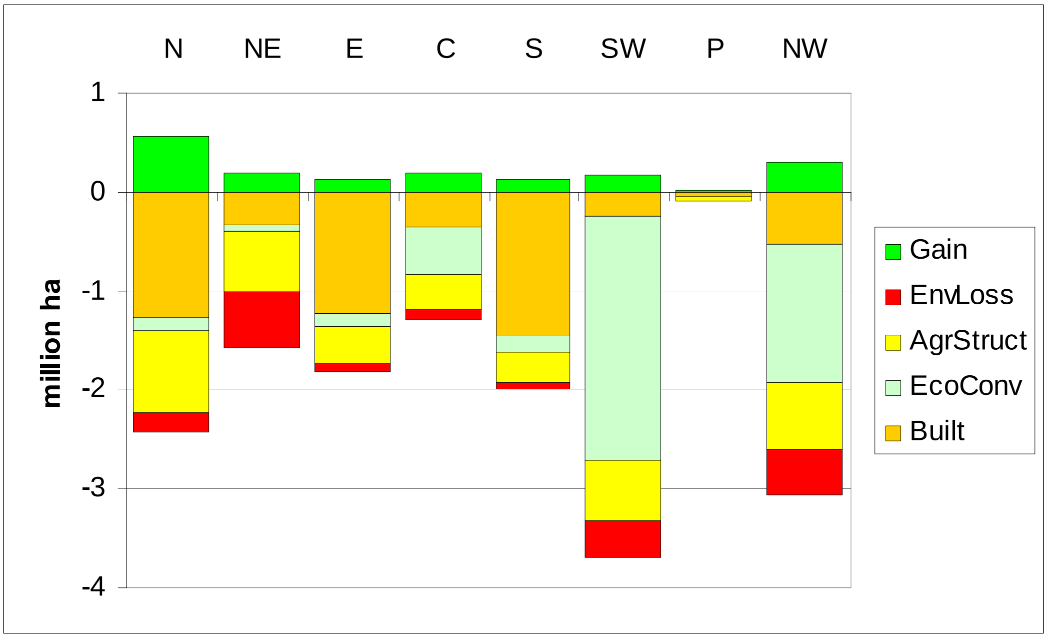
Table 8. Cultivated land (million ha), by region, *BASELINE* scenario

Region	Cultivated land				Irrigated land			
	1996	2020	2030	% change 1996-2030	1996	2020	2030	% change 1996-2030
North	28.1	26.5	25.9	-7.8	16.4	15.8	15.5	-5.9
Northeast	21.5	20.9	20.7	-4.0	4.0	5.1	5.9	48.4
East	13.5	12.5	12.1	-10.3	9.7	9.0	8.6	-11.4
Central	11.9	11.0	10.8	-8.9	8.0	7.5	7.4	-7.5
South	9.9	8.5	7.8	-21.3	5.3	4.5	4.1	-22.2
Southwest	20.5	17.4	17.2	-16.1	6.1	5.9	5.8	-5.1
Plateau	1.1	1.0	1.0	-2.8	0.4	0.4	0.4	-1.5
Northwest	23.6	21.5	21.2	-10.5	8.5	8.2	8.1	-4.4
CHINA	130.0	119.4	116.6	-10.3	58.5	56.4	55.9	-4.5

Source: Simulated according to methodology established in Lu *et al*. (2004).

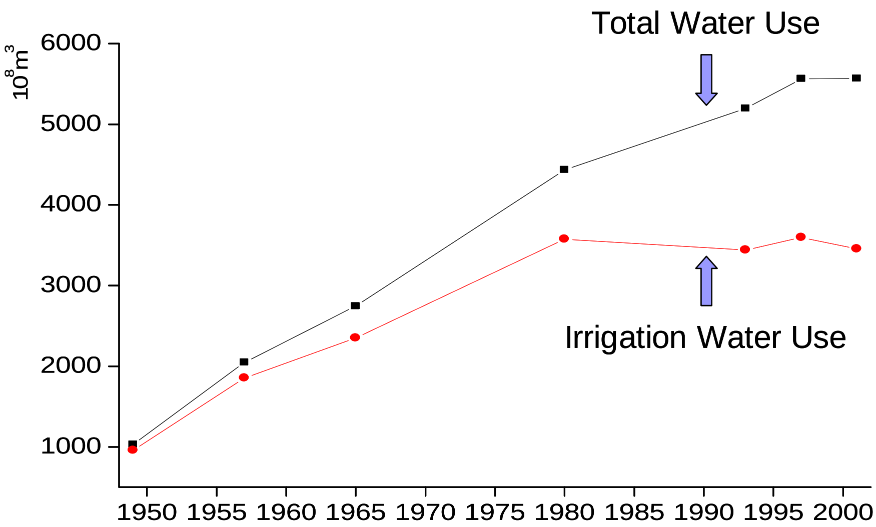
Figure 14 presents regional changes in projected farmland and indicates the main factors causing conversion of cultivated land. In the coastal South, East and North regions the driving factor is conversion to built-up land, whereas ecological conversion is the main reason in the Southwest and Northwest regions in order to restore ecologically fragile cultivated land.

Figure 14. Regional changes in farmland 2000-2030, *BASELINE* scenario.



Note: Gain = additions due to land reclamation; EnvLoss = loss of cultivated land due to environmental hazards, degradation, etc.; AgrStruct = loss of cultivated land due to conversion to orchards, fish ponds, etc.; EcoConv = loss of cultivated land due to ecological conversion to grass or forest land; Built = farmland conversion due to construction.

Figure 15. Changes in total and irrigation water use (Source: MWR, 2002).



In terms of potentials for future expansion of irrigated land, the share in the Northeast is likely to increase, because this is a major grain producing area that has the lowest irrigated share of all regions but plenty of water available (though seasonally and geographically varied). By contrast, in the North region, comprising Beijing and surrounding provinces, water availability is a pressing problem due to fast rising non-agricultural water demand. In the coastal provinces of the South region, the share of irrigation area has been dropping. This trend is expected to continue due to farmland conversion to built-up land and the consequent disruption of irrigation systems (Table 8). The remaining regions are expected to maintain their current share of irrigated land. As water available for irrigation will at best be stagnant and more likely be declining due to competing demands for non-agriculture use in the future, the key to preservation and expansion of irrigated areas lies in a more rational and efficient water use. Ample opportunities are still available to achieve this. Figure 15 indicates that irrigation water use increased sharply during 1950 to 1980 but stagnated thereafter.

Livestock herds

To meet the growing demand for livestock products (see Section 2), China is rapidly moving from traditional natural resource based livestock management to intensified peri-urban and urban production systems. It is virtually impossible to predict the future geographical distribution of the intensified livestock production in any great detail, because massive new investments will be required and the shifts will be determined by a complex set of factors, including developments in infrastructure, availability and economics of feed supplies, changes in relative prices of land, labour and capital, and strength of environmental regulations and their enforcement. Hence, we can only establish scenarios for the geographic distribution of animals and livestock production capacities (termed here stable units or places), which seem plausible based on population projections, demand growth scenarios for animal products, and consideration of environmental factors.

The scenarios on the distribution of livestock production capacities for different management systems were expressed at the provincial and county levels and were generated through simulations outside the CHINAGRO welfare model, applying three principles: (i) the projected future distribution of livestock in confined[7] *traditional* systems is linked to projected changes in rural population; (ii) the geographical distribution and level of pastoral livestock follows projected trends of the availability and productivity of grasslands, taking account of planned grassland improvements and rehabilitation to increase productivity above current natural conditions (Lu et al., 2004); and (iii) the number of animal places (stable units) in the confined *specialized and industrial* livestock systems is expanding to meet (approximately) the projected demand for livestock products at the provincial level (approximately, because the ultimate equilibrium demand is to be determined by the CHINAGRO welfare simulation model). In other words, it is assumed that specialized and industrial livestock systems would compensate for decreases in traditional systems and evolve consistently with demand growth as projected at provincial level[8].

Simulations were based on these three principles, and in all cases led to a general increase of confined livestock relative to pastoral systems, which seems plausible as grassland resources are already under great pressure and further expansion of grass-based livestock systems would involve major efforts to rehabilitate degraded pastures and improve grassland productivity. Hence, in the CHINAGRO simulations to 2030, the production increases are mainly obtained through intensification of confined livestock production, and through shifts from traditional to specialized and large-scale livestock systems. In the CHINAGRO welfare model simulations this in turn has implications for sources and composition of livestock feeds, as well as for average productivity per livestock unit, where two factors combine,

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[7] Confined livestock systems may include post-harvest stubble grazing but are mainly based on feeding of crops, crop by-products and (processed) crop residues, as opposed to grazing systems relying primarily on pastures.

[8] For Beijing and Shanghai, densely populated areas with especially scarce cultivated land, reallocation of the intensive production has been assumed at a rate proportional to projected agricultural land reduction in these provinces.

namely technological progress per livestock system (see below) and the effects brought about by the significant changes in livestock structure, i.e. shares of traditional vs. specialized systems.

Table 9. Livestock units in confined and pastoral systems (10^6 heads), *BASELINE*

Livestock type	Confined				Pastoral				Total Livestock			
	2000 (10^6)	2015 (10^6)	2030 (10^6)	2000-2030 (%)	2000 (10^6)	2015 (10^6)	2030 (10^6)	2000-2030 (%)	2000 (10^6)	2015 (10^6)	2030 (10^6)	2000-2030 (%)
Cattle	73.3	88.7	87.9	+20	20.6	20.9	19.1	-7	93.9	109.6	107.0	+14
Buffaloes, camels, yaks	22.7	21.0	17.8	-22	12.2	13.1	13.9	+14	34.9	34.1	31.7	-9
Horses, mules, donkeys	15.5	14.3	12.1	-22	7.0	7.9	8.8	+26	22.5	22.2	20.9	-7
Sheep, goats	191	250	304	+60	100	112	126	+26	290	362	430	+48
Pigs	408	519	565	+39	-	-	-	-	408	519	565	+39
Poultry	3774	5987	7059	+87	-	-	-	-	3774	5987	7059	+87
Livestock[9] biomass (10^6 t)	78.5	97.0	104.1	+33	13.6	14.4	15.1	+11	92.1	111.4	119.2	+30

Source: Fischer et al., 2005b

The *BASELINE* projections obtained in this way indicate that from 2000 to 2030 the number of livestock units for ruminants in general, and pastoral livestock in particular, will increase at a lower rate than pigs and poultry (see Table 9). Depending on livestock category, increases of livestock herd sizes from 2000 to 2030 vary between 14% and 48%. Poultry numbers increase by nearly 90%. Cattle used for draught power (as well as other animals used for transportation) are strongly decreasing by more than 40%, thereby partly counter-balancing the increases of beef and dairy cattle. Aggregate livestock, measured in terms of livestock biomass, increases by 30%. Estimates range from 11% for pastoral livestock to 33% for confined livestock (including pigs and poultry).

Trade policies

Policy changes due to WTO-accession are already part of the specification used for the *BASELINE* scenario (China joined WTO in December 2001). Existing agreements and commitments regarding tariffs and quota were built into the *BASELINE* scenario assumptions. The setting of policy levers used in *BASELINE*, related to domestic markets and international trade is shown in Table 10.

Technological progress

The simulations with the CHINAGRO welfare model allow for the representation of disembodied technological progress. It is reflected through the growth rate in land and livestock productivity and is related to agricultural R&D investment. It was assumed that increases observed during the past two decades will be maintained in the next 30 years, implying an annual growth rate of 1.2% in land productivity in the cropping sector, and of 1.3% in productivity of animals (overall output per livestock unit) in the intensified livestock production sector. In the current simulations, the simplifying assumption was adopted that

[9] Livestock biomass refers to sum of live-weight of all livestock in a county.

this technological progress will affect all crops on irrigated and rain-fed land equally, and all livestock types of a given livestock system equally.

Table 10. Policy scenarios related to domestic market and international trade (%)

	Import tariff ad valorem (1)	VAT import (2)	VAT domestic (3)	Other, e.g. STE rent (4)	Import tariff equiv. (= 1+2-3+4)	Export subsidy equiv.
Policy in 2001 (Pre-WTO accession)						
1 Rice	1	13	10	3	7	-10
2 Wheat	1	13	10	0	4	0
3 Coarse grains	1	13	10	26	30	31
4 Oilseed crops	3	13	10	14	20	0
5 Sugar crops	40	17	10	0	47	0
6 Cotton	8	15	13	-2	8	10
7 Horticulture	16	15	10	0	21	-7
8 Beef and mutton	45	15	13	0	47	-8
9 Pork and poultry	20	15	13	0	22	-25.5
10 Milk	25	17	15	0	27	0
11 Fish	14	13	10	0	17	-15
12 Other food	30	15	13	0	32	-10
14 Textile	22.5	15	15	0	22.5	-5.25
Post-accession, 2005						
1 Rice	1	13	10	0	4	-5
2 Wheat	1	13	10	0	4	0
3 Coarse grains	1	13	10	0	4	0
4 Oilseed crops	3	13	10	3	9	0
5 Sugar crops	20	17	10	0	27	0
6 Cotton	1	15	13	0	3	0
7 Horticulture	6	15	10	0	11	-3
8 Beef and mutton	12	15	13	0	14	-4
9 Pork and poultry	12	15	13	0	14	-21.5
10 Milk	11	17	10	0	18	0
11 Fish	12	13	10	0	15	-11
12 Other food	15	15	13	0	17	-6
14 Textile	11.5	15	15	0	11.5	0

Source: Huang (2002). Note: Policy scenarios for 2010-2020 are also reported in (Huang, 2002).

5.2. Full liberalization scenario (LIBERAL)

The *full liberalization* scenario *(LIBERAL)* uses the same demographic, economic growth and technology change assumptions as applied in the *BASELINE* scenario. The same holds for land and water resources availability, i.e., the projections of cultivated land and irrigated land are the same in both scenarios. The main difference is in price and border protection policies. In addition to the WTO commitments of the *BASELINE* scenario, the *LIBERAL* scenario assumes a 50% elimination of border protection in 2010 from the 2003 levels, and a full elimination from 2020 onwards.

5.3. High-income growth scenario (HIGHGROW)

The *high-income growth* scenario (*HIGHGROW*) assumes a faster GDP and income growth than other scenarios, driven by higher growth in non-agricultural sectors compared to the *BASELINE* scenario. The simulation stipulates that by 2020 China's GDP will grow to a level of 4.1 times its size in 2000, and by 2030 the total GDP would reach 7.7 times the size in

2000. This implies an average annual GDP growth rate of 7.9% for the period 2001-2010, of 6.7% in the 2010s, and of 6.0% in 2020s, compared to respectively 7.7%, 6.2% and 4.9% in the *BASELINE*.

Higher economic growth is likely to be associated with faster urbanization and higher investment. It is assumed that under the *HIGHGROW* scenario, by 2030, the share of urban population would reach 64%. Higher economic growth and increased investment, combined with more rapid urbanization, causes an additional 3 million hectares of farmland net loss due to conversion into built-up areas. Finally, technical progress would be higher as well, i.e., in *HIGHGROW* an additional 0.25% of annual land productivity growth is added in cropping and an extra 0.1% annually in animal productivity of the intensified livestock production sectors.

5.4. High agricultural R&D investment scenario (TECHPRO)

The *high agricultural R&D investment* scenario *(TECHPRO)* assumes that additional policy efforts would lead to increased funding and investment in agricultural R&D. As a result, productivity in agriculture would increase on top of the *BASELINE* rates of technological progress: an additional 0.5% of annual land productivity growth in cropping, and an extra 0.2% in animal productivity in the intensified livestock production sectors. The parameterization is based on Huang and Hu (2002); they estimate that China's internal rate of return (IRR) of research in agriculture is 55-60%, only slightly lower than the average level observed from 120 technology development studies in Asia (IRR of 67 %), but higher than the world average (IRR of 49 %).

5.5. Enhanced irrigation development scenario (IRRIGUP)

In specifying the *IRRIGUP* simulation experiment the aim was to investigate the impact of an assumed further irrigation expansion. The scenario uses the same demographic, economic and urbanization assumption as *BASELINE*. This also leads to the same trends in farmland conversion as in *BASELINE*, i.e., a total cultivated land of 116.6 million ha in 2030. The main difference is an additional 10% of effectively irrigated land compared to *BASELINE*, increasing irrigated land in 2030 to 61.5 million ha compared to 55.9 million ha in *BASELINE*. The additional irrigated land is distributed among regions according to the analysis and specifications of experts from China Agricultural University (Chen et al., 2005). To maintain the *BASELINE* land balance, rain-fed land was reduced accordingly, e.g., in 2030 from 60.8 million hectares in *BASELINE* to 55.2 million hectares in *IRRIGUP*. The increases of irrigated land in the *IRRIGUP* scenario varied by region as follows: 7% in the North region, Northeast 22%, East 7%, Central 12%, South 7%, Southwest 7%, Plateau 2%, Northwest 12%.

6. A bird's eye view of the CHINAGRO welfare model

The CHINAGRO welfare model was cast in the form of a single-period welfare program that is solved for every year of simulation (1997, 2003, 2010, 2020, 2030) under the scenario assumptions described in the previous section. The specification of this model is best understood in terms of the behaviour it implies for the individual agents.

Consumers

Consumers are distinguished by urban and rural population, by region and by income group (poor, middle, rich). Each individual of a specified group spends revenue on food and non-food according to a linear expenditure system with time-dependent coefficients. This revenue originates from direct earnings as well as from government transfers (which are negative in case an actor pays income tax), set so as to implement social welfare weights as specified by government policy. Hence, consumer demand adjusts to scenario variables as well as to variables set in the model itself, also to be referred to as endogenous variables.

The scenario variables include (a) the population numbers in every group as resulting from natural fertility, death rates and migration across regions and from rural to urban; (b) the shifting coefficients of the demand systems reflecting the change in lifestyle as consumers become richer, including a shift from staples to luxury foods; (c) the social welfare weight of a group as resulting from government policy; (d) the price of non-agricultural commodities. The endogenous variables, with regard to consumers, are the prices of agricultural commodities, at consumer level, i.e., after the appropriate processing from raw material to retail level, and incomes.

Farmers

Farms are being distinguished by county. The typical farm of a county chooses its cropping pattern by allocating its labour and equipment so as to maximize its current revenue, i.e. the net proceeds from sales minus the cost of current inputs (purchased feeds for animals and fertilizer for crops), subject to technological constraints specified separately for different "land use types": irrigated land, non-irrigated land, and several types of livestock systems (ruminant, non-ruminant), with varying degrees of intensification for given stable capacities. The technology of each land use type is represented via a two-branch production function (as illustrated in Figure A1.1 in the Appendix). The upper panel indicates how much fertilizer per hectare (respectively feed per stable unit in case of livestock production), amount *f,* is needed to achieve a given yield *y*. The lower panel shows for a given land use type how much yield can be obtained from given labour per hectare (respectively labour per stable unit).

Each land use type produces outputs of several crop (respectively livestock) commodities, in accordance with specified substitution possibilities. For example, the non-ruminant farm type jointly produces pork, poultry and eggs in county-specific proportions that can change under shifts in the relative prices of these goods. In addition, this farm type produces manure as a by-product that can be used as fertilizer, and hence substitutes for purchased fertilizer. Similarly, cropping systems produce various goods such as grains, vegetables and fruits, as well as by-products such as cereal brans and husks that can be used as feed for livestock. Clearly, ruminants can use feed from pastures as well as other types of roughage and crop products, while non-ruminants are more restricted in feed sources suitable in their diets.

Hence, the supply model employs as trend scenario variables: (a) the area of rain-fed cultivated land, irrigated land, land under tree crops, grazing land, forest land, built-on land; (b) the stable capacities of the various livestock systems; and (c) the total farm labour available. Neutral technological progress enters by specified trends on yield per unit of input. Most importantly, the prices at county level are endogenously and simultaneously determined on the market and enter as determinants of farm supply and input demand.

Traders

Traders minimize for every traded commodity the total cost of delivery they incur to satisfy consumption and input demand, given (i) the supply in the various counties, (ii) the possibility to import from and export to the world market at a given, tariff-ridden price possibly subject to quota on foreign trade, and (iii) the unit cost of transport between regions and the international market, as well as the commodity-specific unit costs for processing the agricultural products up to consumer level. This leads to simultaneous determination of trade levels as well as regional and county prices at which deliveries take place. For this trade module, levels of government taxes, tariffs and quotas are the scenario parameters, describing the policies being implemented in a scenario. The world prices, the scenario trend assumptions on the unit cost of trade, also enter as scenario assumptions.

Equilibrium is found and prices of each region are determined such that the net quantities purchased by consumers and producers in each region coincide with the net deliveries by traders.

Methodological results

In the process of building the CHINAGRO general equilibrium model, which is fully implemented in the GAMS-language (see Brooke et al. 1992), the following methodological results could be obtained (see Keyzer and van Veen, 2005b, for further details):

First, we could prove that the model possesses a solution. Moreover, we could establish that the solution is unique and maximizes social welfare once all policy/institutional distortions are eliminated.

Second, we have specified a modular calibration procedure through which it can be assured that the base-year equilibrium solution of the full welfare program exactly replicates the base-year data (1997 in the current implementation). For consumption, we allow for a smooth transition between different linear expenditure systems, under changes in incomes and prices, and we have specified a separate regression program for its calibration. For interregional trade, we present a new dual programming technique to calibrate flows so as to meet given net export positions of each region, at prices that are sufficiently close to the observed ones and cover the associated transportation costs. Non-agricultural inputs are treated as a closing item to fit the balance of payments. We note that such a modular decomposition of the calibration process is essential for the future maintenance of this data intensive, empirically based model. It makes it possible to keep database operations fully separate from the modelling work, while improvements in the database are in a transparent way transmitted to the model outcomes. Also, future replacements in specific model components can be implemented without requiring a new calibration of the complete model. Moreover, initialization at a fully calibrated base-year solution provides a large number of checks and clues for scrutinizing correctness of programming and integrity of data during the debugging phase of model building, and also speeds up computation.

Third, we have specified a globally convergent algorithm to solve this very large optimization model. The algorithm decomposes the problem in two components, one a multi-regional exchange component that maximizes social welfare of consumers while treating the output and input of the 2,433 counties as given. It is solved as a regular medium-sized convex program (via a MINOS *solve* statement in GAMS). The other one is an agricultural supply module consisting of a series of county-specific farm-income maximization programs that take prices as given and are solved with a tailor-made algorithm that terminates in a finite number of iterations and has an exact solution. This property of finite and exact termination makes it possible to embed both components within a price-adjustment outer loop (implemented through parameter adjustments in GAMS) and to prove global convergence.

The algorithm proves to be remarkably fast and precise. For example, the computational performance is as follows. Starting from given scenario data files and estimates of the consumer demand system, the model calibration and preparation of GAMS input files for simulation take about 25 minutes, on a regular laptop (Pentium®, 4-M CPU, 512MB RAM, 1.70 GHz). A five-period simulation (1997, 2003, 2010, 2020, 2030) plus tabulation is completed within 20 minutes, at a precision of .08% for every regional commodity price in every year.

7. Results of the CHINAGRO model simulations

The simulations with the CHINAGRO welfare model have produced a variety of interpretable results. In this summary report we focus on model-based findings concerning some key agricultural issues: China's grain security; agricultural value added and incomes from farming; impacts of trade liberalization; and environmental pressures related to livestock intensification.

7.1. Changes in food demand structure and implications for grain security

Academics have expressed different opinions and views on the current agricultural policies and the seriousness of concerns regarding grain security. Various questions have been raised: Will China's grain supply turn into a serious problem? What is the likely situation regarding China's grain demand and supply balance in the next 3 decades? What are the key determinants of China's future grain security? Can China rely on long-term productivity growth for grain security?

The CHINAGRO model simulations indicate that China can meet its domestic demand for rice and wheat, the two dominant food grains in the country, in all scenarios (Table 11). Self-sufficiency in rice and wheat has been regarded as a guarantee for the country's food security. In this regard, the results obtained in the CHINAGRO simulations are optimistic and encouraging. However, the simulated close match of demand and supply of major food grains is not a result of significant increases in production but rather a consequence of relative stagnation in aggregate demand. As indicated in Table 11, while the cumulative growth in *BASELINE* demand of rice and wheat between 2000 and 2010 is about 4%, the momentum is reduced to 3.5% between 2010 and 2020 and turns negative (a change of –1.6%) between 2020 and 2030.

Two factors contribute to this stagnation in aggregate demand. First, the consumption levels of food grains in both rural and urban areas are already high (Figure 16) and there is a low or even negative propensity among those in the high-income groups to spend extra income on food grains. Second, there are significant differences between rural and urban food consumption habits. The per capita consumption of cereals in urban lifestyles is typically 30% lower than that in the rural diets (Figure 16). When urbanization will bring several hundred millions of rural people into urban lifestyles in the coming three decades, the corresponding shifts in diet structure will lead to a stagnation of aggregate food grain demand due to a nearly 10% decline in average per capita consumption of cereals during 2000 to 2030, even though per capita incomes in both population segments will increase significantly in these decades.

Figure 16. Per capita consumption of food grains (kg/cap), *BASELINE* scenario

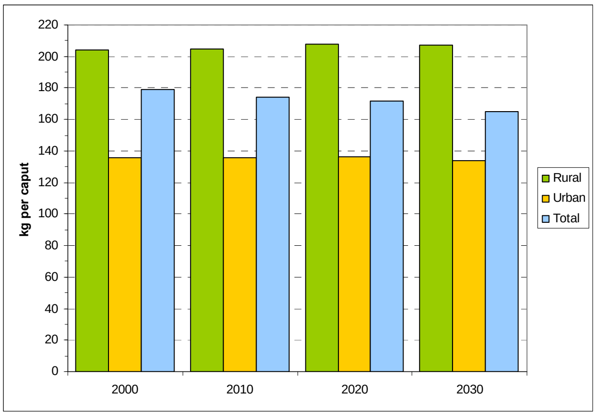
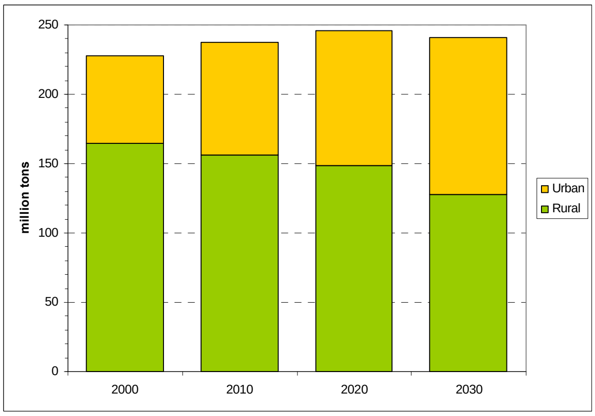


Figure 17. Aggregate consumption of food grains (million tons), *BASELINE* scenario



Notes: Estimate of year 2000 represents average of simulations for 1997 and 2003. Rice consumption is included as milled equivalent, wheat as flour equivalent.

According to our model calculations, urban food consumption of cereals accounted for less than 30% in 2000; this proportion will become nearly 50% by year 2030 (Figure 17). Due to migration and population momentum, total aggregate food grain consumption in rural areas is projected to decrease by more than 20% relative to year 2000, whereas aggregate urban consumption of grains will increase by about 80% compared to level in 2000.

Figure 18. Per capita consumption of meat and eggs (kg/cap), *BASELINE* scenario

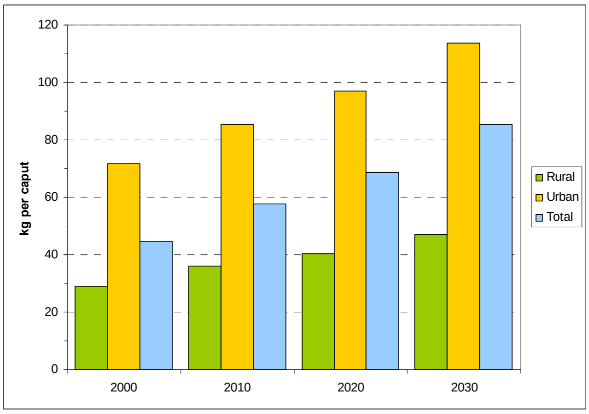
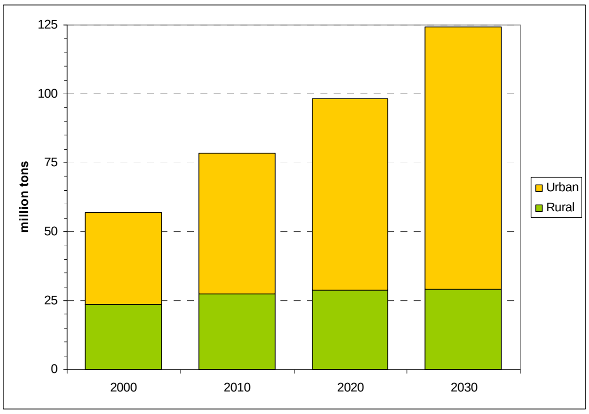


Figure 19. Aggregate consumption of meat and eggs (million tons), *BASELINE* scenario



Notes: Estimate of year 2000 represents average of simulations for 1997 and 2003.

While urbanization is reducing the growth momentum of food grain consumption it will likely accelerate increases in meat consumption. Urban diets include a higher level of meat and egg consumption and per capita meat consumption is responding strongly to income growth among both rural and urban population. Urbanization in combination with strong income growth leads to a significant rise in per capita consumption of meat and eggs: from

44.6 kg per capita in 2000[10] to 85.3 kg in 2030 (Figure 18), which still falls a few kg below the present-day average of industrialized countries of 89.9 kg per capita, 18.5 kg below the reported EU-15 average consumption, and about 50 kg below the average reported for United States in the FAO Food Balance Sheets (FAO, online database at http://faostat.fao.org). In the *BASELINE* simulations the above factors in combination result in more than doubling of total aggregate meat and eggs demand between 2000 and 2030 (Table 11; Figure 19).

Although the simulations suggest a lasting security in food grain supply, the basic question will soon shift from the traditional formulation, whether farmers will be able to feed China's huge population, to a new one, namely how farmers can raise and feed the required animals to meet future demand for livestock products. Related to this is the question whether, if China were to rely on imports, it should import meat, or import feed grains for raising the livestock.

Table 11. Supply, demand, net outflow and self-sufficiency rate of major food items under different scenarios (million tons and %).

	BASELINE				LIBERAL	HIGHGROW	TECHPRO	IRRIGUP
	2000	2010	2020	2030	2030	2030	2030	2030
Supply								
Rice, milled	131.3	137.2	143.1	143.6	146.5	148.6	174.8	156.2
Wheat, flour	88.9	89.1	92.1	90.5	91.1	90.2	102.0	91.8
Maize	114.2	109.7	114.4	112.2	109.2	115.0	137.4	112.3
Beef and mutton	4.7	5.6	6.7	7.3	7.4	7.3	7.3	7.3
Pork, poultry, eggs	54.5	75.0	96.9	114.1	113.5	117.4	122.0	114.0
Demand								
Rice, milled	131.0	137.2	142.4	140.2	139.8	137.4	140.6	140.6
Wheat, flour	86.6	89.0	92.1	90.5	91.1	90.2	95.3	91.8
Maize	105.0	123.2	135.7	136.6	136.4	136.2	137.4	136.4
Beef and mutton	4.7	5.6	6.4	6.9	7.0	7.3	6.9	6.9
Pork, poultry, eggs	54.2	75.0	93.8	119.4	123.5	125.7	120.5	119.4
Net outflow								
Rice, milled	0.3	0.0	0.7	3.4	6.7	11.1	34.2	15.6
Wheat, flour	2.4	0.1	0.0	0.0	0.0	0.0	6.7	0.0
Maize	9.2	-13.5	-21.3	-24.4	-27.2	-21.3	0.0	-24.1
Beef and mutton	0.0	0.0	0.2	0.4	0.4	0.0	0.4	0.4
Pork, poultry, eggs	0.3	0.0	3.1	-5.3	-10.1	-8.3	1.5	-5.4
Self-sufficiency (%)								
Rice, milled	100	100	100	102	105	108	124	111
Wheat, flour	103	100	100	100	100	100	107	100
Maize	109	89	84	82	80	84	100	82
Rice and Wheat	101	100	100	102	103	105	118	107
Cereals	103	97	96	96	96	99	113	100
Beef and mutton	101	100	104	106	105	100	106	106
Pork, poultry, eggs	100	100	103	96	92	93	101	95
Meat and eggs	101	100	103	96	93	94	101	96

Notes: Estimates of year 2000 represent the average of simulations for 1997 and 2003. Aggregation of cereals for self-sufficiency calculation was done in terms of primary equivalent (wheat, maize, paddy rice). Supply, demand and net outflows are given in million tons. Self-sufficiency denotes ratio of supply (production plus net from-stock changes) over demand (private consumption, feed use, losses, and net to-stock changes).

Given the comparative cost advantage of China in livestock production, especially in terms of cheap labour and animal housing costs, the CHINAGRO model simulations suggest that

[10] The figure for year 2000 represents the average of simulations for 1997 and 2003.

China's livestock production sectors can meet domestic demand for meat and eggs for the years 2010 and 2020, falling short of aggregate demand only in the last simulation decade to 2030 (see Table 11). This scale of simulated livestock production is subject to imports of significant quantities of feed grains and protein feeds (Table 12).

Table 12. Demand, net outflow and self-sufficiency rate of major feed sources in different scenarios (million Gcal and %).

	BASELINE				LIBERAL	HIGHGROW	TECHPRO	IRRIGUP
	2000	2010	2020	2030	2030	2030	2030	2030
Demand								
Maize, feed	303	366	411	418	417	420	420	418
Carbohydrate feed	312	327	338	320	319	322	321	319
Protein feed	228	276	312	319	318	320	320	318
Local feeds	623	658	691	700	700	689	700	701
Tradable feed	843	968	1061	1057	1053	1063	1062	1055
Total feed	1466	1627	1752	1757	1753	1752	1762	1756
Net outflow								
Maize, feed	27	-40	-64	-75	-83	-66	0	-74
Carbohydrate feed	-9	-11	-15	-5	-3	-7	39	-3
Protein feed	-34	-73	-102	-109	-107	-106	-69	-102
Tradable feed	-16	-125	-181	-189	-193	-179	-30	-179
Self-sufficiency (%)								
Maize, feed	109	89	84	82	80	84	100	82
Carbohydrate feed	97	96	96	99	99	98	112	99
Protein feed	85	73	67	66	66	67	79	68
Tradable feed	98	87	83	82	82	83	97	83
Total feed	99	92	90	89	89	90	98	90

Notes: Estimates of year 2000 represent averages of simulations for 1997 and 2003. Local feeds include grass, crop residues, household wastes, water plants, etc. Carbohydrate feed includes minor and low quality grains, tubers, molasses, and vegetable feed. Protein feed includes cereal brans from wheat and rice, protein cakes from soybeans, rapeseed, cottonseed, etc., and fish meal (see Appendix A2, Table 2.5). Aggregation of feed sources for self-sufficiency calculation was done in terms of energy content. Demand and net outflows are given in million Gcal. Self-sufficiency denotes ratio of supply from domestic sources (production plus net from-stock changes) over feed demand (and net to-stock changes).

The year 2030 aggregate meat and egg net import in *BASELINE* scenario amounts to 4.9 million tons (Table 11), representing about 4% of total demand. In the *HIGHGROW* scenario, with stronger economic growth and faster urbanization, aggregate meat and egg consumption increases 5.4% above the level of the *BASELINE* scenario and net imports increase to 8.3 million tons. Only the *TECHPRO* scenario, with its emphasis and investment on R&D in agriculture, generates productivity gains, which are sufficient to achieve full self-reliance in meat production, with 1.9 million tons net exports of meat and eggs in 2030.

For example, in the *BASELINE* for year 2020, Table 12 indicates a net import of feed maize at a level of 64 million Gcal, representing 16% of the total feed use of maize of some 115 million tons in that year, and a net import of protein feed at a scale of 102 million Gcal (covering nearly one-third of the total protein feed demand). The latter is approximately equivalent to 32 million tons of soybean cake. For 2030 net imports are respectively 75 million Gcal feed maize and 109 million Gcal protein feed. In all decades production and demand are nearly balanced for carbohydrate feeds. In terms of overall feed self-reliance ratios for tradable feeds, the *BASELINE* scenario starts from a fairly balanced picture (self-sufficiency ratio of 98%) decreasing to 82% in 2030, i.e., relying on nearly one-fifth of (tradable) feed sources to be provided from outside. Taking into account grass and fodder from pastures, use of crop residues for feeding, and use of various other 'local' feed sources, the balance improves and the estimated feed supply from domestic sources in 2030 accounts for just under 90% of feed demand compared to 99% in 2000 (Table 12). The resulting self-sufficiency for 2030 is quite similar in the alternative scenarios, except for the *TECHPRO* scenario where feed self-sufficiency is nearly maintained at the 2000 level due to lasting productivity gains achieved with higher agricultural R&D investments.

Net imports of 50-60 million tons of animal feeds (mainly maize and protein feed) and of 5-10 million tons of meat are unquestionably significant. Such a large-scale net import of animal and crop products might challenge the capacity of the world food and feed markets, in addition to the pressure it would generate on transportation and logistics systems. Therefore, these figures suggest that maintaining the historical pace of technical progress, as observed in the last two decades, could be insufficient for China's crop and livestock sectors to cope with the increasing domestic demand for meat.

If meat demand were to increase as projected, the current set of scenario simulations indicates only one effective solution, namely productivity and resource-use efficiency gains connected with research and farmers' education. Under the High R&D *TECHPRO* scenario, China's cropping sector would be able to produce enough maize and carbohydrate feeds and would leave only a small net import gap for protein feed at a scale similar to the net import level in 2003. Furthermore, China's livestock sector would generate a self-sufficient rate of 101% for 2030. This result suggests that China does have the potential to feed the increasing number of animals through higher agricultural R&D investment. This ability does not come for free and would require substantial efforts on top of the observed historical trend.

At the regional level, the picture is rather diverse in terms of feed sources (Figure 20 and 21) as well as food and feed self-reliance (Table 13 and 14; Figure 22 and 23). Feed sources in the pastoral Plateau and Northwest regions are dominated by grassland and pastures where local feeds contribute 80%-90% of total feed use in 2000. In all other regions local feed sources (grass, crop residues, household wastes, etc.) have contributed less than 50% to regional feed use. Though we assume in *BASELINE* that growing shares of improved grassland in total grassland as well as an increase and better utilization of available crop residues will still add to local feeds, their relative importance in animal feeding will nevertheless decrease over time, from 44% of total feed energy supply in 2000 to less than 40% in 2030.

Figure 20. Structure of national and regional feed use in 2000, *BASELINE* scenario

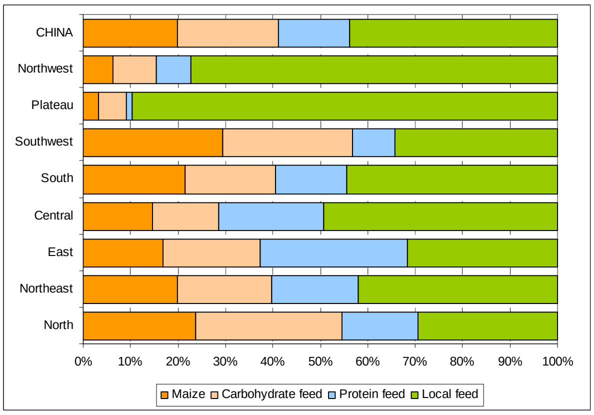


Figure 21. Structure of national and regional feed use in 2030, *BASELINE* scenario

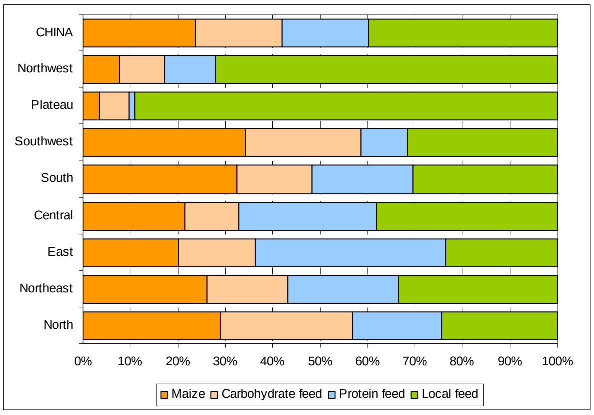


Figure 22. Regional cereal self-reliance ratios in 2000 and 2030, *BASELINE* scenario

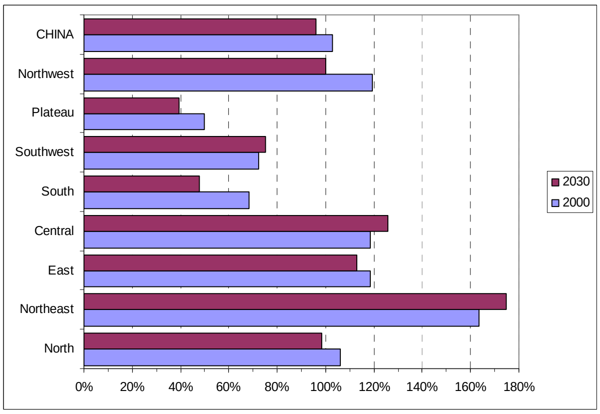
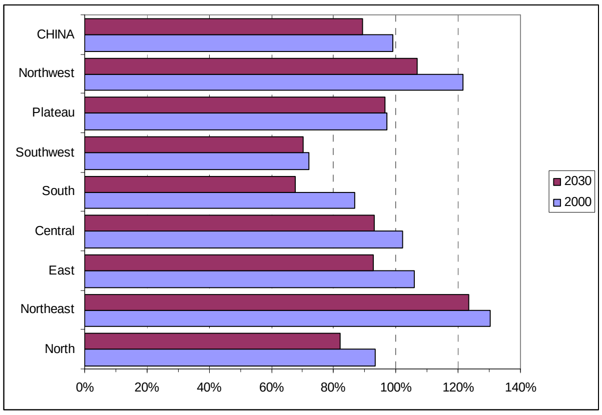


Figure 23. Regional feed self-reliance ratios in 2000 and 2030, *BASELINE* scenario



For the current situation (average of 1997 and 2003 simulations) two regions stick out as relatively large excess suppliers of cereals and feed, the Northeast and the Northwest regions, each with a simulated net outflow of tradable feed in the order of 40 million Gcal (equivalent to 11-12 million tons of maize). The base-year simulations indicate a cereal and feed surplus also for the Central and East region. The largest net inflows were simulated for the South and the Southwest region (including Sichuan and Chongqing) (Table 13; Figure 22 and 23). Between 2000 and 2030 the self-reliance in food, feed and meat decreases in most regions (Table 13 and 14). The largest decrease occurs in the South region where cereal self-sufficiency drops below 50%. Both Northeast and Northwest maintain an export position throughout the *BASELINE* simulations, especially for feed grains.

Table 13. Demand, net outflow and self-sufficiency of major commodities, by region, average of 1997 and 2003 *BASELINE* simulations (million tons and %).

	North	North-east	East	Central	South	South-west	Plateau	North-west
Demand								
Rice and Wheat	80.1	22.4	57.2	51.1	51.2	52.1	1.8	27.0
Maize	31.3	12.6	8.2	8.2	11.1	32.8	0.6	5.7
Vegetable oil	2.8	1.0	2.3	1.9	1.4	1.4	0.1	0.9
Sugar	1.8	0.5	1.9	0.9	1.8	1.2	0.0	0.5
Meat and eggs	14.1	5.2	10.6	6.8	9.1	9.2	0.3	3.1
Cereals	111.5	34.9	65.4	59.3	62.3	84.9	2.5	32.7
Net outflow								
Rice and Wheat	-2.1	-0.8	14.5	16.3	-11.4	-6.7	-0.6	-5.1
Maize	8.9	23.0	-2.5	-5.4	-8.4	-16.7	-0.6	11.4
Vegetable oil	-0.5	-0.3	-0.6	-0.2	-0.9	-0.6	0.0	0.1
Sugar	-1.7	-0.1	-1.8	-0.6	2.3	0.0	0.0	0.2
Meat and eggs	1.5	0.7	-2.3	0.9	-1.9	1.0	0.1	0.1
Cereals	6.8	22.2	12.0	11.0	-19.8	-23.4	-1.2	6.4
Self-sufficiency (%)								
Rice and Wheat	97	96	125	132	78	87	65	81
Maize	128	283	69	34	24	49	5	300
Vegetable oil	82	69	72	88	33	59	121	113
Sugar	4	86	4	38	231	98	0	137
Meat and eggs	111	114	78	113	79	110	121	103
Cereals	106	164	118	118	68	72	50	119

Notes: Aggregation of cereals was done in terms of primary equivalent of paddy rice, wheat, and maize. Regional demand and net outflows are given in million tons. Self-sufficiency denotes ratio of regional production over regional use and is given in percent.

Table 14. Demand, net outflow and self-sufficiency rate of major commodities, by region, year 2030 *BASELINE* simulations (million tons and %).

	North	North-east	East	Central	South	South-west	Plateau	North-west
Demand								
Rice and Wheat	83.7	22.5	58.2	48.3	70.0	47.9	2.5	31.6
Maize	41.2	15.1	9.8	11.2	19.9	36.9	1.1	8.5
Vegetable oil	3.1	1.1	2.4	1.9	2.0	1.5	0.1	1.3
Sugar	2.7	0.6	2.4	1.2	2.8	1.7	0.1	0.8
Meat and eggs	31.0	9.1	21.3	13.1	25.8	16.7	0.6	7.2
Cereals	124.9	37.6	67.9	59.6	89.9	84.8	3.6	40.1
Net outflow								
Rice and Wheat	-1.5	9.3	13.0	24.1	-29.6	0.4	-1.1	-9.2
Maize	-0.6	18.8	-4.4	-8.9	-17.3	-21.4	-1.1	9.1
Vegetable oil	-0.8	-0.4	-0.8	-0.2	-1.5	-0.7	0.0	-0.1
Sugar	-2.6	-0.2	-2.4	-0.9	1.2	-0.4	-0.1	-0.1
Meat and eggs	0.2	2.5	-5.7	2.2	-5.7	1.4	0.1	-0.2
Cereals	-2.0	28.1	8.6	15.3	-46.9	-21.0	-2.2	0.0
Self-sufficiency (%)								
Rice and Wheat	98	141	122	150	58	101	56	71
Maize	99	225	55	21	13	42	3	207
Vegetable oil	74	60	65	88	24	54	101	88
Sugar	2	68	3	27	143	75	0	84
Meat and eggs	101	127	73	117	78	108	118	98
Cereals	98	175	113	126	48	75	39	100

Notes: Aggregation of cereals was done in terms of primary equivalent of paddy rice, wheat, and maize. Regional demand and net outflows are given in million tons. Self-sufficiency denotes ratio of regional production over regional use and is given in percent.

For meat and eggs two regions were projected to require net imports in the range of 20-30% of regional demand in 2030, namely the wealthy East and South. While more than doubling the base-year meat imports, the calculated regional self-reliance ratios decrease only modestly, respectively from 78% to 73% for the East region and from 79% to 78% for the South.

7.2. Agricultural value added and incomes from farming

The simulations with the CHINAGRO welfare model indicate that the role of agriculture in the national economy will be significantly diminished. This represents a continuation of the trend observed in the past, when rapid economic growth has been accompanied by sharp structural changes in the economy. While agriculture accounted for more than 30% of GDP prior to the economic reforms in 1979, by 2000 the share of agriculture had fallen to 16%. The share of service sectors in the national GDP increased from 13% in 1970 to 21% in 1980 and 33% in 2000. The share of industry remained relatively stable at around 45-50% (Huang et al., 2003d).

In the *BASELINE* scenario, farm value added grows at an average annual rate of 2.5% (see Table 15), compared to 6.6% per annum for non-farm value added during 2000 to 2030. Hence, the calculated share of farm value added in total value added declines to about 40% of its level in the base year. The model results indicate some regional variation: for the Northeast and Southwest regions the share of farm value added in total value added decreases to respectively 55% and 45% of its base year level, whereas the largest relative decrease occurs for the East and Plateau region where this ratio reduces to 30% of its base year value.

Table 15. Value added and net income from farming, by region, *BASELINE* scenario.

	Farm value added (billion Yuan)					Net income from farming (Yuan per person-year in agriculture)				
Region	2000	2010	2020	2030	% p.a.	2000	2010	2020	2030	% p.a.
North	201	287	388	422	2.5	3322	5048	7413	9333	3.5
Northeast	87	126	175	199	2.8	6884	10876	16756	23099	4.1
East	171	219	275	294	1.8	4755	6657	9307	11874	3.1
Central	166	225	297	325	2.3	4965	7232	10461	13490	3.4
South	169	264	403	463	3.4	5381	8481	13067	16524	3.8
Southwest	153	227	306	321	2.5	3011	4691	6845	8334	3.5
Plateau	5	6	8	8	1.5	3576	4356	5118	5652	1.5
Northwest	83	115	149	162	2.2	3762	5322	7121	8634	2.8
CHINA	1037	1470	2001	2194	2.5	4169	6252	9147	11583	3.5

Source: CHINAGRO model simulations.

As a consequence of the shift in diet structure towards meat, the structure of value-added in the agricultural sector will experience significant changes as well. While in 2000 the value-added in the livestock sector accounted for a little more than one-third of the total in the agricultural sector, by 2030 it will contribute more than two-thirds of the total under all scenarios. The simulated magnitude of the value-added in the livestock sector in 2030 was 5.8 times that in 2000 under the *BASELINE* scenario and 6.3 times that in 2000 under the *TECHPRO* scenario, implying an annual growth rate of respectively 6.1% and 6.4%. Despite of such significant expansion, the growth rates of value-added in the livestock sector, which is much larger than simulated growth for cropping, will still lag behind the annual growth of non-agricultural GDP by 0.6 and 0.3 percentage points respectively under the *BASELINE* and *TECHPRO* scenarios.

In the model simulations this development results in a growth gap between national GDP and agricultural GDP. One might expect that out-migration of agricultural labour force to other sectors would push up the value added per farmer, thus narrowing down such growth gap in a per capita sense. However, our model simulations indicate that the out-migration of labour force from the agricultural sector will likely be insufficient to compensate for the differences in sectorial growth. As the number of farmers (agricultural labour in person-year equivalent) is projected in the *BASELINE* to decrease by about 25% during 2000 to 2030, the per capita net farm income will grow faster than farm value added (Table 15), on average by 3.5% annually. This is still significantly lower than the average annual 5.9% per capita GDP growth. The gap between the annual growth rate of per capita GDP and that of the net income (value-added) per farmer is between 2.2 percentage points (*TECHPRO* scenario) and 2.7 percentage points (*LIBERAL* scenario). While outcomes in terms of agricultural production and national self-sufficiency are quite different for the *TECHPRO* and *HIGHGROW* scenarios, it is interesting to note that they produce a similar growth path for per capita farm value added (see Table 16), though for different reasons. Increased agricultural R&D expenditures in the *TECHPRO* scenario lead to higher land and livestock productivity and thus higher per capita farm incomes. In the *HIGHGROW* scenario on the other hand, the faster economic growth and more rapid urbanization result in less people dependant on agriculture and thus per capita farm incomes increase as well.

Table 16. Farming value added under different scenarios, by region.

Farming value added (billion Yuan)	North	North-east	East	Central	South	South-west	Plateau	North-west
BASELINE 2000	201	87	171	166	169	153	5	83
BASELINE 2030	422	199	294	325	463	321	8	162
HIGHGROW 2030	427	203	303	332	471	331	8	170
TECHPRO 2030	440	213	322	353	502	349	9	170
LIBERAL 2030	391	186	262	309	414	312	7	156
Growth 2000-30 (%)								
BASELINE	2.5	2.8	1.8	2.3	3.4	2.5	1.5	2.2
HIGHGROW	2.5	2.9	1.9	2.3	3.5	2.6	1.6	2.4
TECHPRO	2.6	3.0	2.1	2.5	3.7	2.8	1.8	2.4
LIBERAL	2.2	2.6	1.4	2.1	3.0	2.4	1.1	2.1
Growth per caput 2000-30 (%)								
BASELINE	3.5	4.1	3.1	3.4	3.8	3.5	1.5	2.8
HIGHGROW	3.7	4.4	3.4	3.6	4.1	3.7	1.7	3.1
TECHPRO	3.6	4.4	3.4	3.7	4.1	3.7	1.8	3.0
LIBERAL	3.2	3.9	2.7	3.2	3.4	3.3	1.1	2.7

Notes: Estimates of year 2000 represent averages of simulations for 1997 and 2003. Growth per caput refers to rate of growth in farm value added per person year of agricultural labour between 2000 and 2030.

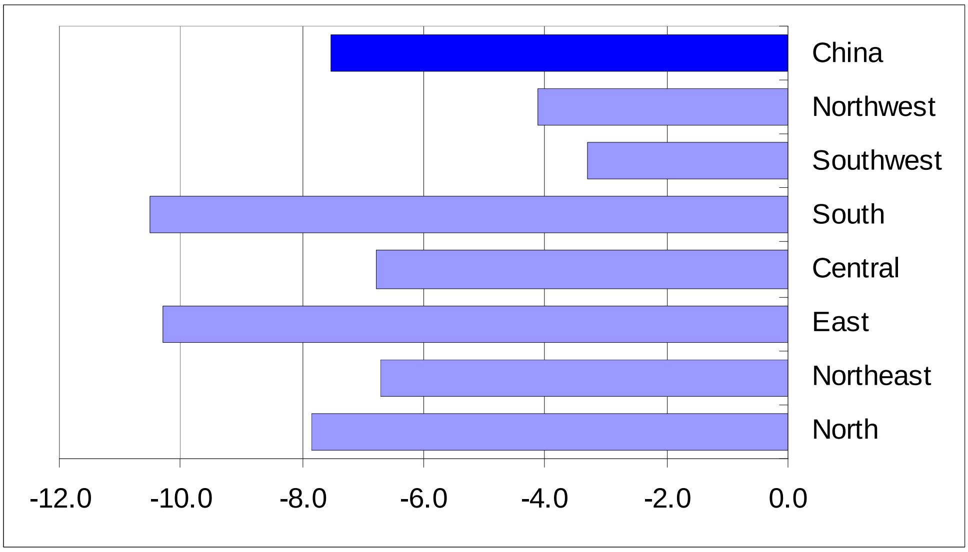
The growing income gap, as suggested by our model simulations, indicates that based on current agricultural policies and widely accepted scenarios of the pace of urbanization, it would become even less attractive for a household to earn all its income with agricultural activities. Interpreting this finding in a proactive way, it suggests that major policy reforms are needed to increase the attractiveness of agriculture to an income earning comparable with prospects in other sectors. In addition, the pace of out-migration of agricultural labour may need to be accelerated. In this regard, the "New Rural Development Program", which was initiated in early 2006, is an important policy move towards reversing the growing gap between farming and non-farming incomes. This policy package includes abolition of agricultural tax, direct income support to farmers, input subsidies, and a large increase in agricultural R&D spending and rural infrastructure investment. If well implemented and further strengthened, it could make a big difference. In contrast, new policy initiatives to accelerate the pace of labour out-migration from the agricultural to non-agricultural sectors are still rare. Therefore, farm households will be able to avoid a widening income gap relative to other sectors only if a growing share of income can be obtained from off-farm activities.

7.3. Impacts of full trade liberalization

In the *LIBERAL* scenario we have investigated the potential impacts of full agricultural trade liberalization. The main difference is in price and border protection policies. In addition to the WTO commitments of the *BASELINE* scenario, the *LIBERAL* scenario assumes a 50% elimination of border protection in 2010 (from the 2003 levels), and a full elimination from 2020 onwards.

Full removal of border protection beyond currently planned levels results in a reduction of agricultural value added of 7.5% in model simulations to 2030 (compared to *BASELINE* scenario) but also a gain in consumer welfare as expressed, for example, in higher meat consumption per caput of nearly 4%. The simulation results indicate that inland regions are still insulated from competition even after full removal of border protection due to high trade and transportation margins. While coastal provinces, especially in East and South region, experience a reduction of agricultural value added of more than 10%, the reduction of agricultural value added relative to the *BASELINE* scenario is only less than 4% in the Southwest and Northwest regions.

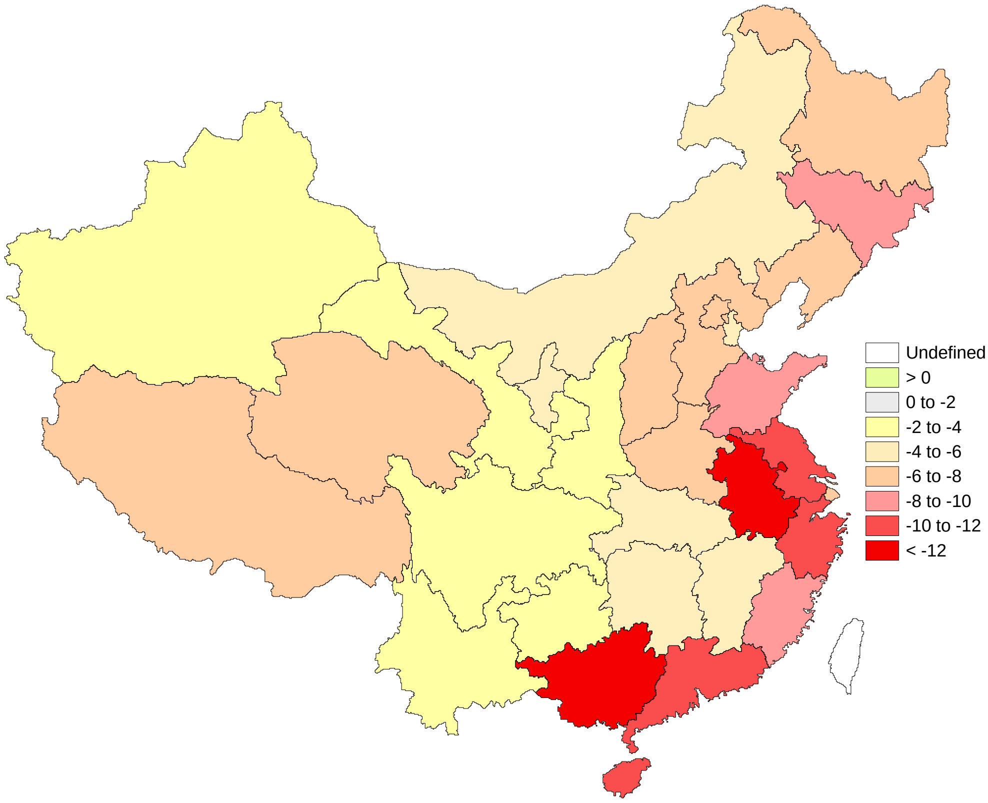
Figure 24. Impacts of full trade liberalization on regional value added of farming in 2030, *LIBERAL* scenario relative to *BASELINE* scenario (% change).



In this connection, some important aspects of the economic geography of the country need to be noted. First, several major urban concentrations are situated along the coast and, except in the delta region, separated from the hinterland by hill tracts. Since inland transport is more expensive than ocean shipping, especially when transporting from locations in rugged or hilly terrain, this gives foreign suppliers a significant cost advantage. In other words, at competitive pricing of products it may be cheaper to export meat or feed grains from New York or Rotterdam to Shanghai than from the Red Basin where much of the livestock is being produced; similarly, transporting maize from the Northeast of China to the Southwest may be as costly as importing it from overseas. Secondly, this argument works also the other direction. Farmers located inland are in general well positioned to serve local markets. Their location gives them a considerable advantage in supplying nearby population concentrations with agricultural products as compared to foreign exports. Thirdly, in Western Europe and the United States pork and poultry production and dairy are generally produced either close to the consumer or close to harbours. This is because harbours offer good sites for food processing plants that provide much of the animal feeds, e.g., through processing of oilseeds, and for bulk imports. In China this creates a handicap for inland farmers who may, also in view of their small farm size and already intensive cultivation, have only limited alternatives to improve their agricultural incomes.

Figure 25 illustrates the spatial distribution of the simulated impacts of full agricultural trade liberalization (*LIBERAL* scenario) on province-level value added of farming in 2030. The results highlight that the economic costs of trade and transportation have effects similar to protection and taxation. Their reduction improves efficiency but will also reduce the insulation of farmers from competition. This effect is critical for the income position of farmers in regions with limited scope for improved agricultural productivity and lack of off-farm opportunities.

Figure 25. Spatial impacts of full trade liberalization on value added of farming in 2030, *LIBERAL* scenario relative to *BASELINE* scenario (% change).[11]



7.4. Environmental pressures from agriculture

The CHINAGRO simulations suggest a nearly full utilization of projected stable capacities, which were generated by a separate simulation model as presented in Section 5. The geographical distribution and increasingly intensive utilization of stable spaces are expected to cause growing environmental hazards through nutrient burden from concentrated pig and poultry systems. Where agricultural land available for manure disposal and recycling is insufficient and where modern facilities to convert manure into biogas and solid fertilizers are lacking, such nutrient burden will cause land and water pollution. Without appropriate treatment this will inevitably increase environmental risks and hygienic pressures on human health. Environmental impacts are mainly associated with significant pollution of surface and groundwater caused by mismanagement of animal excreta, emissions of manure-related gasses into the atmosphere (methane, nitric and nitrous oxide, etc.), and overload of soils by nutrients.

In 2000, the aggregate amount of manure produced by stall-fed and otherwise confined livestock in China is estimated to be in the order of 1.4 billion tons annually (Fischer et al.,

[11] Values shown for Plateau region refer to change of value added from rain-fed cropping and pastoral livestock.

2005)[12]. This equates to approximately 10.3 tons of manure per hectare of cultivated and orchard land per year. In the *BASELINE* scenario, this amount of manure from confined animals increases to more than 1.9 billion tons in 2030, equating to 15.3 tons per hectare of then available cultivated and orchard land. Pigs and poultry produce about 45% of nutrients of the manure in 2000. For 2030, the share contributed by pigs and poultry increases to 54% due to changes in livestock mix as well as changes in production systems.

The composition of manure varies in terms of nutrients, contents of heavy metals and organic matter depending on livestock category and production system, applied manure management, feeding characteristics and manure type. Manure nutrients – primarily comprising nitrogen (N), phosphate (P2O5) and potassium (K2O) - together account for an estimated 1.4 percent (in weight) of the total manure of confined animals in 2000; for pastoral livestock the estimated average is about 1.1 percent. We calculated nutrients contained in manure of confined livestock at county level and then aggregated them to provincial, regional and national levels. For China as a whole, the current amount of nutrients from manure of confined animals is estimated to be in the order of 8.4 million tons nitrogen, 5.1 million tons phosphates and 5.8 million tons potassium or respectively 60 kg nitrogen, 37 kg phosphates, and 42 kg potassium per hectare cultivated and orchard land (Table 17 and 18).

Table 17. Total manure nutrients from confined livestock (million tons), by region, *BASELINE* scenario.

Region	2000			2015			2030		
	N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O
North	2.4	1.5	1.8	3.1	1.9	2.2	3.4	2.1	2.4
Northeast	0.8	0.5	0.5	1.0	0.6	0.6	1.0	0.6	0.6
East	0.8	0.5	0.5	1.1	0.7	0.6	1.2	0.7	0.6
Central	1.0	0.6	0.5	1.2	0.7	0.6	1.3	0.8	0.7
South	1.0	0.6	0.6	1.5	0.9	0.8	1.8	1.0	0.9
Southwest	1.8	1.1	1.2	2.3	1.4	1.5	2.6	1.6	1.6
Plateau	0.1	0.0	0.1	0.1	0.1	0.2	0.2	0.1	0.2
Northwest	0.6	0.4	0.6	0.9	0.6	0.8	1.1	0.7	0.9
CHINA	**8.4**	**5.1**	**5.8**	**11.2**	**6.8**	**7.3**	**12.5**	**7.7**	**8.1**

Source: Fischer et al., 2005b.

In 2030, under the *BASELINE* scenario, the corresponding figures would be in the order of 12.5 million tons nitrogen, 7.7 million tons phosphates and 8.1 million tons potassium or respectively 100 kg nitrogen, 61 kg phosphates, and 64 kg potassium per hectare cultivated and orchard land. This represents an increase of nutrient supply in manure per hectare of cultivated land of 53-67% at the national level. It is worth noting that the relationship between manure nutrients supply and available cultivated land varies considerably across regions (Table 18).

In practice, only part of the nutrients contained in livestock manure is recycled in cultivated land. Losses of nutrients occur in livestock housing and in all stages of manure storage and handling prior to application to cultivated land[13]. In China, the recycling of liquid manure in

[12] In this environmental assessment it was assumed that manure from pastoral livestock was recycled on the grazing land or, to a limited extent, was used as domestic energy source for heating and cooking.

[13] Manure losses in livestock housing and manure storage facilities are causing point-source pollution. Apart from excess nutrients, the manure may contain insecticides, fungicides, drugs used for livestock, and disease pathogens. They may cause pollution of surface and drinking water and create disease risks.

cultivated land or grassland is generally not implemented due to lack of incentives/legal framework, absence of technologies adapted to prevailing infrastructural conditions, field sizes and cropping systems. The liquid manure is generally directly or indirectly disposed of to surface- and groundwater, and in some locations is already causing hazardous water contamination and human health problems (Menzi, 2001).

Table 18. Intensity of manure nutrients from confined livestock (kg nutrients/ha cultivated and orchard land), by region, *BASELINE* scenario.

Region[14]	2000			2015			2030			Change 2000-2030 (%)		
	N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O
North	79	48	60	104	64	75	119	74	84	52	53	38
Northeast	34	20	24	44	26	29	47	28	30	37	38	25
East	56	33	33	79	47	43	91	55	48	63	64	47
Central	74	44	42	101	60	53	109	65	55	47	49	31
South	84	49	51	134	79	75	195	115	104	133	134	107
Southwest	57	42	66	134	94	150	207	145	232	261	244	251
Northwest	27	17	23	41	26	35	50	33	43	87	89	85
CHINA	**60**	**37**	**42**	**86**	**52**	**56**	**100**	**61**	**64**	**65**	**67**	**53**

Source: Fischer et al., 2005b.

Problems of environmental pollution and soil overloads from intensive livestock production are further magnified by the concurrent increase of chemical fertilizer uses associated with intensifying crop production. The level of crop production anticipated for China in the next thirty years will require further increases of fertilizer application. Table 19 reports estimates of chemical fertilizer use in the model simulations. It indicates that fertilizer demand at the national level is projected to increase from the present level of 33 million tons of N, P2O5 and K2O in year 2000 to 46 million tons in 2030. This increase implies an average annual fertilizer consumption growth rate of about 1%. Table 20 summarizes fertilizer use intensity, i.e., application per hectare of cultivated and orchard land.

Table 19. Fertilizer consumption (million tons), by region, *BASELINE* scenario.

Region	2000			2015			2030		
	N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O
North	7.2	2.8	0.7	9.1	3.6	1.0	10.3	3.9	1.2
Northeast	2.2	0.6	0.2	2.8	1.0	0.3	3.3	1.2	0.4
East	4.4	1.3	0.3	4.6	1.5	0.4	4.8	1.6	0.5
Central	3.0	1.1	0.4	3.4	1.3	0.5	3.9	1.4	0.5
South	2.5	0.7	0.6	2.5	0.8	0.6	2.1	0.7	0.5
Southwest	2.9	1.0	0.2	3.3	1.2	0.2	3.9	1.3	0.3
Plateau	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0
Northwest	2.3	0.9	0.1	2.6	1.0	0.2	3.0	1.1	0.2
CHINA	**24.5**	**8.5**	**2.5**	**28.4**	**10.3**	**3.2**	**31.3**	**11.1**	**3.6**

Source: Fischer et al., 2005b.

[14] The Plateau region has mainly grass-based livestock systems and includes only very limited cultivated land, less than 0.05 percent of the region's territory. Due to these special circumstances, results for confined livestock systems are irrelevant to judging environmental risks from livestock intensification and were omitted.

Table 20. Fertilizers use (kg/ha cultivated land), by region, *BASELINE* scenario.

Region	2000			2015			2030			Change 2000-2030 (%)		
	N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O
North	239	92	22	309	121	33	362	138	42	51	50	91
Northeast	98	26	8	130	44	14	152	53	18	55	104	125
East	299	92	22	333	112	30	370	124	35	24	35	59
Central	231	87	31	279	103	38	321	113	42	39	30	35
South	205	61	54	226	72	58	235	77	60	15	26	11
Southwest	135	46	8	174	61	13	206	69	16	53	50	100
Plateau	54	25	3	58	26	4	62	26	4	15	4	33
Northwest	96	36	5	116	44	7	135	49	9	41	36	80
CHINA	**177**	**61**	**18**	**217**	**79**	**25**	**249**	**88**	**29**	**41**	**44**	**61**

Source: Fischer et al., 2005b.

Fertilizer losses occur at all stages of fertilizer storage and handling, both prior to and during application to cultivated land. Even with proper fertilizer management, a considerable share of the nutrients is not available for crop uptake. The losses may vary depending on the soil type, type of fertilizer and application practices. In field conditions, crops generally cannot take up more than half of the nitrogen fertilizer that is applied, and of the rest only little remains in the soil for the next crop. Hence, the other 50 percent of nitrogen is leached into the groundwater, is lost in volatization, run-off and denitrification. In field conditions, the extent to which any of these processes prevail depends on environmental conditions and management. In this study typical average values for fertilizer losses were assumed, i.e., for nitrogen, phosphate and potassium respectively 50%, 50%, and 25% (FAO, 1995).

Since detailed parameters on capacity of soils in uptake or sorption of chemical nutrients were not available for most of China's soil types and cropping zones, we had to apply a less rigorous definition of nutrient losses, i.e. the estimated difference between nutrients contained in used chemical fertilizers and livestock manure less the nutrients that are taken up by crop production. The major factors causing nutrient losses can be classified into *point-source losses* and *non-point losses*. The former refers to the losses in the form of emissions to atmosphere and percolation to ground and surface water from location-specific sources such as livestock housing/stables, manure storage facilities, and liquid manure disposal. The latter refers to losses from fertilizer and manure application to cultivated land or from grazing livestock in pasture areas. The non-point nutrient losses have two components. A first part comprises 'non-effective' nutrients, i.e., nutrients not reaching the crop (including losses due to emissions, runoff and percolation), which depends on the environmental setting and nutrient application practices. These losses occur independent of crop uptake capacity. A second part consists of ineffective nutrients that reach the crop root zone, but are in over-supply of crop uptake capacity.

By a detailed nutrient balance accounting (Fischer et al., 2005b), it was estimated that supply of nutrients in excess of crop uptake capacity accounted for one-eights of total nutrient losses. The remainder was due to other forms of point-source and non-point losses in fertilizer application and manure handling.

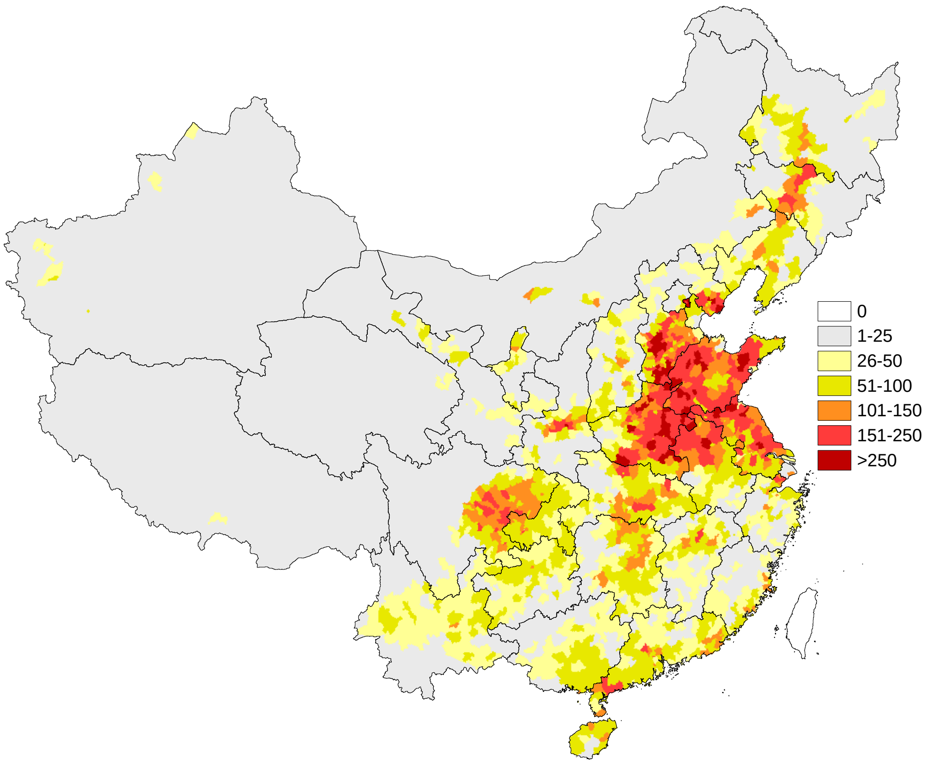
Table 21 shows that for year 2000 the average nitrogen release associated with crops and livestock production in China is estimated at 2.2 tons per square kilometre, increasing to 2.9 tons in 2030. Highest overall environmental pressure, as defined here, occurs in the East and North regions, due to the importance and intensity of agriculture in these provinces, with estimated more than 8 tons of nitrogen released per square kilometre in 2000, i.e. nearly 4 times the average. Average estimated releases of phosphates in 2000 amount to 0.9 tons per square kilometre, increasing to 1.2 tons per square kilometre in 2030. Again, highest intensities occur in the North and East regions, respectively 3.6 and 2.9 tons of phosphates released per square kilometre in year 2000, projected to increase to respectively 4.9 tons and 3.4 tons per square kilometre.

Table 21. Intensity of nutrient losses (kg/ha total land), by region, *BASELINE* scenario.

Region	2000			2015			2030		
	N	P2O5	K2O	N	P2O5	K2O	N	P2O5	K2O
North	81.1	35.6	12.3	100.6	45.0	15.8	112.5	49.0	18.0
Northeast	23.9	7.5	4.1	28.2	10.6	5.0	30.5	11.8	5.4
East	83.8	28.9	8.0	89.3	33.6	10.3	91.1	33.9	11.4
Central	40.9	17.6	7.8	46.9	20.0	9.1	51.0	20.7	9.4
South	42.1	15.2	8.7	46.9	18.9	10.7	47.3	20.5	11.7
Southwest	27.7	12.2	6.9	32.8	15.3	8.9	36.8	16.7	10.0
Plateau	2.4	1.5	2.4	2.9	1.8	2.9	3.3	2.1	3.4
Northwest	6.7	3.2	2.5	7.6	3.8	3.1	8.6	4.2	3.7
CHINA	**22.5**	**9.3**	**4.8**	**26.1**	**11.4**	**5.9**	**28.5**	**12.4**	**6.7**

Source: Fischer et al., 2005b.

Figure 26. Intensity of nitrogen losses (kg nutrients/ha total land), *BASELINE* scenario, 2030.



A robust conclusion derived from this accounting suggests that any effective reduction of environmental pressures from intensive crop and livestock production requires targeting point-source losses of manure utilization as well as non-point losses during storage and application of fertilizers and manure. To visualize the environmental pressure caused by such nutrient losses, we use an indicator of the intensity of nutrient losses, measured as the total nutrient losses per hectare of the total territory of a county. Figure 26 presents intensities of nitrogen losses for 2030 under the *BASELINE* scenario, showing the distribution and highlighting some "hot-spots" of environmental pressures associated with release of nutrients in agricultural activities (for comparison, see Figure 8 in Chapter 3 for a map of estimated intensity of nitrogen losses in 2000).

Finally, combining these results of intensity of nutrient losses with county-level information on population distribution, the analysis indicates for the year 2000 that some 430 counties have intensities of nutrient losses of more than 100 kg per hectare of the county's total territory; about 27% of China's population, or almost 350 million people, lived in these counties with more than 100 kg nutrient losses per hectare of land. In the year 2030 simulations the number of counties with nutrient losses of more than 100 kg/ha territorial land increased to almost 550 and the percentage of population affected reached 32% (over 460 million people).

8. Summary of policy-relevant conclusions

The general aim of the study on *"Policy Decision Support for Sustainable Adaptation of China's Agriculture to Globalization (CHINAGRO)"* has been to engage in an informed policy dialogue between institutions in China and the EU on the realization of improving China's food security, increasing farmer's income and achieving sustainable agricultural development, based on a joint specification and analysis of a range of development and policy scenarios over a 30-year time horizon, from 2001 to 2030. The CHINAGRO project is contributing a unique, solid, and most comprehensive database for the research communities of social scientists and natural scientists in the field of agriculture and rural development, as well as for Chinese policy making bodies.

In the last phase of the project, attention was increasingly paid to dissemination activities. First, the CHINAGRO team organized a special session on 'Sustainable Adaptation of China's Agriculture to Globalization' in the International Conference on 'Globalization, Market Integration, Agricultural Support Policy and Smallholders', held in Nanjing (November 8-9, 2004). There were about 250 participants from China's government, domestic universities and institutes, and international organizations.

Second, to provide an overview of the basic assessment tool and to share some important findings with a wider policy and scientific audience in China, a "Policy Forum on China's Agriculture Toward 2030" and a "Workshop on Policy Decision Support System for China's Sustainable Agricultural Development" were organized by CHINAGRO at the Beijing International Convention Center, Beijing on 14 January 2005. The Policy Forum targeted the policy makers, the Workshop addressed researchers by providing a background and summary of the CHINAGRO methodology, insights into the data integration and verification process, some details of key scenario elements (namely, land use change, irrigation development, and trade policy), and an overview and sample results of the scenario analyses. More than 70 participants from a range of Chinese ministries and academic institutions as well as international organizations in China attended the Policy Forum, and some 60 of them also attended the Workshop.

The Policy Forum presented three themes of critical importance to China's policy and agricultural development: (i) China's Grain Security to 2030 (presentation by Jikun Huang, CCAP), (ii) Catering to Future Needs: Challenges for Farmers, Traders and Government (presentation by Michiel A. Keyzer, SOW-VU), and (iii) Sustainable Agricultural Development (presentation by Günther Fischer, IIASA). Presentations were based on simulation results obtained with the CHINAGRO welfare model and key results were summarized in policy briefing notes.

The results were highly appreciated and well received by the attending policy makers from China and the officials from the Delegation of EU Commission in Beijing. In the closing session of the Workshop, options for further use and extensions of the CHINAGRO model and simulation tools were discussed. In particular, further capacity building of Chinese partners was recommended so that the models developed in CHINAGRO could be fully absorbed and start playing real roles in China's decision making.

Policy-relevant outcomes

From the simulation experiments carried out in CHINAGRO we summarize a few policy relevant conclusions. Of the main conditioning factors shaping magnitude and structure of future demand for agricultural products, demographic changes, urbanization and substantial per capita income growth will play a key role.

Demography and lifestyles:

- Due to the demographic momentum, China's population will grow until 2030 by about 12 to 15% above its level in 2000, to about 1450 million people in 2030. In absolute numbers this means a growth of about 175 million people, i.e., less than 40% of the population increase of 448 million that has occurred during the last 30 years, from 1970 to 2000.
- Important changes in lifestyles are expected to result from substantial projected income growth and urbanization. We project the level of urbanization to fall within a range of 55 to 65% in 2030 compared to 36% in 2000. This means that the 460 million urban population of year 2000 will approximately double by 2030. With a projected average annual GDP growth of 6% to 7%, per capita incomes will increase manifold. The big changes in income and urbanization will have profound impacts on demand structure and levels.
- Having many more and wealthier consumers in urban conditions will have profound impacts on demand. We expect human grain consumption to remain relatively stable whereas consumption of livestock and fish products will approximately double, with major implications for agriculture development.
- Total food consumption of cereals is projected to remain close to current levels. Two factors combine to produce this outcome. First, food energy consumption levels are already high and wealthier consumers tend to substitute for staples with higher value foods such as livestock products and vegetables. Second, urban consumers have lower per capita consumption levels of cereals than rural people; hence, urbanization will result in overall lower average per capita consumption of cereals.
- While urbanization is slowing down cereal consumption it will likely accelerate increases in meat consumption. Urban diets include higher consumption of meat and per capita meat consumption is responding strongly to income growth. We project consumption of livestock and fish products to approximately double. The argument is that both income growth and a growing number of consumers adopting urban lifestyles will reinforce the growth in meat consumption. At the projected level of per capita meat consumption,

urban China in 2030 (i.e., about 850 million people) would be approaching the current per capita meat consumption of industrialized countries.

The simulation experiments in CHINGRO help to understand the dynamics of the supply-demand matching for every major food item at the local and regional markets and to reveal the major interaction between domestic supply-demand gaps and international trade.

Challenges for farmers and traders

- The CHINAGRO model simulations indicate that China can meet its domestic demand for rice and wheat, the two food grains of overriding importance in guaranteeing China's food security in its long history. However, the simulated close match of demand and supply of major food grains is not a result of significant increases in production but rather a consequence of relative stagnation in aggregate cereal food demand.
- In contrast, urbanization and income growth will lead to a significant rise in per capita consumption of meat and eggs, from 45 kg per capita in 2000 to about 85 kg in 2030. At the aggregate level, the *BASELINE* simulations indicate a more than doubling of total meat and eggs demand between 2000 and 2030. Therefore, the basic food-security question will no longer be phrased as to whether farmers can feed China's vast population, but rather be concerned with how farmers can feed the required vast number of animals. Related to this is the question whether, if China were to rely on imports, it should import meat, or import feed grain for raising the livestock. In this connection, some important aspects of the economic geography of the country need to be noted.
- The CHINAGRO simulations suggest that China will raise livestock mainly domestically. Under reference conditions this will require imports of feed grains and protein feeds at a scale of 50-60 million tons in 2020s, being eventually also supplemented by some imports of meat in 2030. These results are largely induced by China's comparative cost advantages in livestock production. However, such comparative advantages could be significantly weakened in the 2020s as a consequence of changes in relative prices of major production factors across sectors, increase in environmental pressure caused by intensive livestock production, and possibly a rise of feed prices in international markets. Therefore, these figures suggest that maintaining the historical pace of technical progress, as observed in the last two decades, could be insufficient for China's crop and livestock sectors to cope with the increasing domestic demand for meat. Only with an additional emphasis and investment on R&D in agriculture could generate productivity gains that are sufficient to achieve full self-reliance in food and feed grain as well as meat production.
- The simulations with the CHINAGRO welfare model indicate that the role of agriculture in the national economy will be significantly diminished. In the baseline simulations, farm value added grows at an average annual rate of 2.5%, compared to 6.6% per annum for non-farm value added during 2000 to 2030. The model simulations indicate that the out-migration of labour force from the agricultural sector, based on widely accepted scenarios of the pace of urbanization, will likely be insufficient to compensate for the differences in sectorial growth. Interpreting this finding in a proactive way, it suggests that major policy reforms are needed to increase the attractiveness of agriculture to achieve an income earning comparable with prospects in other sectors. In addition, the pace of out-migration of agricultural labour may need to be accelerated. The "New Rural

Development Program", which was initiated in early 2006, is an important policy move towards reversing the growing gap between farming and non-farming incomes.

Trade liberalization:

- Full removal of border protection beyond currently planned levels results in a reduction of agricultural value added of 7.3% in model simulations to 2030 (compared to *BASELINE* scenario) and a significant gain in consumer welfare as expressed, for example, in higher meat and egg consumption per caput of nearly 3.5%.
- There are important aspects of the economic geography of the country that must be noted. First, several major urban concentrations are situated along the coast and, except in the delta region, separated from the hinterland by hill tracts. Since inland transport is more expensive than ocean shipping, especially when transporting from locations in rugged or hilly terrain, this gives foreign suppliers a significant cost advantage. At competitive pricing of products it may be cheaper to export meat or feed grains from New York or Rotterdam to Shanghai than from the Red Basin where much of the livestock is being produced; similarly, transporting maize from the Northeast of China to the Southwest may be as costly as importing it from overseas. Secondly, in Western Europe and the United States pork and poultry production and dairy are generally produced either close to the consumer or close to harbours, which offer good sites for food processing plants that provide much of the animal feeds, e.g., through processing of oilseeds, and for bulk imports. In China this creates a handicap for inland farmers who may, also in view of their small farm sizes and already intensive cultivation, have only limited alternatives to improve their agricultural incomes.
- The simulation results indicate that inland regions are still insulated from competition even after full removal of border protection due to high trade and transportation margins. While coastal provinces (in East and South region) experience a reduction of agricultural value added of more than 10%, the reduction of agricultural value added relative to the *BASELINE* scenario is less than 4% in Southwest and Northwest regions.
- The results highlight that the economic costs of trade and transportation have effects similar to protection and taxation. Their reduction improves efficiency but will also reduce the insulation of farmers from competition. This effect is critical for the income position of farmers in regions with limited scope for improved agricultural productivity and lack of off-farm opportunities.
- In the model simulations the impact of sustaining technological improvements is by far more important for the model outcomes than the effect of fully removing remaining border protection. Results underscore the importance of R&D spending.

The CHINAGRO scenarios portray a realistic picture of likely resource trends of land and water availability for agriculture and highlight the possibility and risks of increasing environmental pressures.

Land, water and environment:

- Economic growth and urbanization will forcefully compete for agricultural resources of land and water. We estimate that another 7 to 9 million hectares of farmland will be converted to built-up land up to 2030, i.e., 5% to 7% of farmland in year 2000. The effect will be much larger for the South (17% to 25%) and the East (12% to 17%) regions.

- Despite of current legislation and efforts, we expect that not all conversion to built-up land can be compensated by land reclamation and restoration. It is estimated that the stock of farmland in 2030 would be in the range of 113 to 118 million hectares compared to 128 million hectares in 2000.
- Irrigation water is essential for China's high grain output from limited farmland. We estimate that 72% of grain output in 2000 is produced on irrigated land. For rice, the share contributed from irrigated land is well over 90%, for wheat more than 85%. On the other hand, major feed commodities, maize (45% from irrigated land) and soybeans (< 30% from irrigated land), currently come from dominantly rain-fed production.
- Intensive livestock systems will play the leading role in meeting the increasing demand for meat in the future. Pig stocks in intensified systems are expected to increase at least 3 to 3.5 times, broilers 4.4 to 5 times, and layers 2 to 2.4 times. As a consequence, while in 1997 about two-thirds of pig production came from traditional small-scale farming and one-third from specialized and large-scale enterprises, it is expected that this relation will reverse and traditional farming will account for only about one-third of pig output in 2030.
- Pastoral livestock will grow much less than confined livestock, an estimated growth around 10%. Total (pastoral and confined) livestock is projected to increase by about 30% during 2000 to 2030. This estimate takes into account the counter-balancing effects of an expected significant 40% to 50% reduction of large animals used for work and transportation.
- Due to further intensification of agricultural production in both crop and livestock sectors, we estimate that with current rates of efficiency the environmental pressures stemming from nutrient concentration and overload would increase by at least one-third. It is of high importance to improve fertilizer use efficiency and balance of nutrients application, and to plan for environmentally adequate ways of livestock manure treatment and recycling.
- Projected increases of confined livestock coincide with a decrease of cultivated land available for nutrient recycling. This inevitably leads to a considerable increase of nutrient supply in manure per hectare of cultivated land. For the *BASELINE* scenario, total amounts of nitrogen, phosphate, and potassium increase in the range of 40% to 50% in 2030 compared to 2000, and in terms of nutrients per hectare of then available cultivated land China-wide by 50% to 67%. Manure nutrients production per available cultivated land varies considerably across regions.
- As greenland ecosystem services and environmental goods are largely outside the market, the Government has crucial roles to play in combating environmental degradation.

China's efforts and success in increasing food and fibre supply to meet food needs of its growing population in the past 50 years have been well recognized. China has shifted from a food net importer to net exporter since the early 1980s and became one of the developing countries with the highest food and grain self-sufficiency, which has significantly contributed to world food security (FAO, 2003). In the coming decades, importing 5% or even 10% of grain (mainly feed) is feasible for China and should not be considered as a threat to national grain security. The main directions that China can follow to protect its future grain security are to continue investing in agricultural technology, to invest in increasing the efficiency of agriculture in general and of water use in particular, and to promote poverty reduction programs that will provide the poorest of China's households with a way to procure sufficient quantities of grain and other foods.

To ensure the nation’s food security in the future, to cater to the food preferences of richer and more urbanized consumers, to mitigate widening rural-urban as well as regional income disparities, and to prevent massive environmental pollution, China needs to make fundamental changes in the national food policies and in refocusing the priorities of grain security. Some major policy implications are summarized below:

- A shift in the emphasis of grain security is recommended from all grain to food grain. In order to maintain the spirit of China’s food and grain security policies without imposing excessively costly and ineffective restrictions, the national government should redefine its grain security goals in terms of rice and wheat, the two major food grains. This would provide considerable protection against any external economic threat while being attainable without causing major distortions.
- A shift in the emphasis from aggregate national food supply to household food accessibility is indicated. While China’s aggregate supply of food grains is not expected to encounter serious problems, there will nevertheless be millions of households in disadvantaged rural areas with an income level at or below the relative poverty line. The main focus of national food security policy should therefore be placed on these households and measures should be implemented that raise average incomes in these areas and buffer these households against income shocks.
- China’s national food grain security should rely mostly on raising long-run productivity. Subsidy programs such as the “Program of Direct Cash Subsidy for Grain Production” that was implemented in early 2004 are very costly and thus trim down the government’s fiscal resources available for public services. In contrast, investment in agricultural R&D, farmer education, water-saving irrigation technology, and in other rural infrastructure will provide a long-run safeguard for food grain security.
- Great efforts should be taken to ensure that investment policies will enhance productivity and improve efficiency of land and water resources use in major grain producing regions. This is particularly important in North, Northeast and Central China. With growing regional specialization and trade, investments on market infrastructure are also critical.
- As water supply available for agriculture will be stagnant or even declining in the future, the key to maintaining or even expanding irrigated areas lies in more rational and efficient use of water.
- Geography plays a major role not only in environmental differences but also in economic matters. This needs to be reflected in policy analysis and formulation, which must be geographically differentiated. The simulation results highlight that the economic costs of trade and transportation have effects similar to protection and taxation, even after full removal of border protection. Their reduction improves efficiency but will also reduce the insulation of farmers from competition. This effect is critical for the income position of farmers in regions with limited scope for improved agricultural productivity and lack of off-farm opportunities.
- The increasing meat demand can be met domestically only through rapid introduction of intensified livestock systems. To prevent environmental pressures stemming from nutrient concentration and overload, it is of high importance to improve fertilizer use efficiency and balance of nutrients, and to plan for environmentally adequate ways of livestock manure treatment and recycling.

- The quantitative assessment of current and future environmental nutrient loads associated with crop and livestock production highlights the importance of policy measures that enhance nutrient management and reduce pollution, such as:
  - Establishing of monitoring systems for environmental impacts of excess nutrients;
  - Introducing effective economic and legal policies to provide incentives to farmers for taking proper action to reduce livestock pollution;
  - Improving technologies and management of nutrient application to crop land; and
  - Providing incentives for allocation of livestock production in areas where a large quantity of livestock feed is produced with substantial untapped capacity for nutrient recycling in cropland and where current livestock densities are low.
- Without adequate measures – technological, financial, and legislative – to cope and prevent existing and looming environmental problems, various hot-spots of agro-environmental pressures may suffer irreversible environmental impacts. This especially concerns the densely populated areas where intensive livestock and crop production may also increase human health risks.

The CHINAGRO model is now fully operational and accounts in considerable depth and detail for the spatial diversity of China's social and environmental conditions. Nevertheless, from the perspective of integrated regional planning, further steps should be taken to secure and extend the solid achievements of the CHINAGRO project. The proposed further development of the model system should concentrate on three aspects, namely to: (i) improve realism of the behavioural response and functioning of markets as well as representation of policies and institutions at provincial level; (ii) further extend the representation of water and the environment in the welfare model so as to more fully incorporate the feedback from crop and livestock sectors to the resource base and human health; and (iii) continue efforts to broaden the base of trained researchers in China that would update, extend, and apply the model to regional planning tasks.

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Appendix A.1. A summary description of the CHINAGRO welfare model

A competitive equilibrium is an allocation of commodities, in which consumers maximize their utility subject to a budget constraint, producers maximize profits subject to a technology constraint, both types of economic agents take prices as given, and total demand does not exceed total supply. The main properties of the competitive equilibrium are laid down in two welfare theorems: The First Welfare Theorem says that a competitive equilibrium is Pareto efficient and the Second Welfare Theorem states that any Pareto efficient allocation can be achieved as a competitive equilibrium with transfers (e.g. Ginsburgh and Keyzer, 1997). Hence, distributional considerations can be met through transfers, and there is no need to use the price mechanism for this. Consequently, there is room to let the price mechanism operate freely.

An important result that forms the bridge between these two fundamental theorems states that any Pareto efficient allocation can, provided utility functions are well behaved, be expressed as a welfare optimum with given welfare weights on individual utilities. Finally, the Negishi Theorem says, that there exist weights, such that the solution of the welfare program corresponds to a competitive equilibrium without transfers. These fundamental results imply that the computations can be performed within the context of a welfare program.

The CHINAGRO welfare model implements a welfare optimum, distorted by prevailing indirect taxes and tariffs. Hence, it assumes compensating income transfers to be provided that maintain fixed welfare weights among consumers. We abstain from imposing budget constraints with given transfers for every household or consumer group separately for the following reasons. First, our description of the non-farm sector in the Chinese economy is rudimentary at best. This makes it difficult to derive a realistic distribution of primary income over household groups. Second, data on income distribution within regions are only available for total expenditure and not by source of income. Third, several public redistributive mechanisms are currently in place that would have to be analyzed as well. Finally, but this is not a major reason, calculations are somewhat easier with fixed welfare weights.

A1.1. The multi-region, multi-commodity welfare model

Let counties be indexed by *c, c = 1,…,2433*, and regions be indexed *r*, *r = 1,…,8*. These indices appear as subscripts and are also taken to distinguish between site-, region- and county-level for both variables and functions, e.g. x_c from x_r and ω_c from ω_r.

We consider all goods simultaneously, but some, such as the commodity used in transport, can be purchased at a fixed price. The variables of this model are *K*-dimensional vectors with commodities indexed $k = 1, \cdots, K$ as elements. We write $'$ for the vector transpose. The transport costs are represented through the *K*-dimensional vectors $\theta_{rr'}$ of inter-regional transport requirements, i.e. demand for non-agriculture as input, and the *K*-dimensional vector of intra-regional transport requirements τ_c^+, τ_c^-. Similarly, ζ_r^+ and ζ_r^- denote the transport and processing requirements for international trade from the border to the region and vice-versa. Let z_c^+ and z_c^- denote the commodity inflow into and outflow from a county *c*; and m_r^+ and m_r^- denote the import to and export from region *r*. The total input demand g_r for inter- and intraregional transport is:

$$g_r = \sum_{r'} \theta_{rr'}{}' v_{rr'} + \sum_{c \in C_r} (\tau_c^+{}' z_c^+ + \tau_c^-{}' z_c^-) + \zeta_r^+{}' m_r^+ + \zeta_r^-{}' m_r^- , \tag{A1.1}$$

where C_r denotes the set of counties in region r and the products of vectors denote inner products.

The economy is an open economy and it trades with the outside world at given foreign market prices. The general equilibrium welfare model imposes a balance of payments constraint. At given import prices $\overline{p}_r^+$, and export prices $\overline{p}_r^-$, such that $\overline{p}_r^- < \overline{p}_r^+$, the imports from the outside world m_r^+ should not exceed exports m_r^- incremented by a given, possibly negative trade deficit $\overline{B}$:

$$\sum_r (\overline{p}_r^+{}' m_r^+ - \overline{p}_r^-{}' m_r^-) \leq \overline{B} . \tag{A1.2}$$

We note that regions without direct access to foreign markets through seaports or border crossings have $\overline{p}_r^- = 0$ and $\overline{p}_r^+ = +\infty$, i.e., they may trade with neighbouring regions, which in turn may trade with foreign markets.

Within every region, consumers are classified as being either rural or urban depending on the population density in the site s they live in. The superscripts u and v distinguish between urban and rural variables and functions (v for village to avoid the confusion if we were to use r for both rural and regional). Urban consumers are dealt with at regional level, rural consumers at county level, indexed c, for $c = 1,...,2433$. The general equilibrium model requires utility to be in money metric. The welfare function performs the conversion from site-specific utility to money metric through given, positive welfare weights α_r^u, α_r^v which make utilities comparable across consumers:

$$W = \sum_r \alpha_r^u u_r^u (x_r^u) + \sum_r \sum_{c \in C_r} \alpha_c^v u_c^v (x_c^v) , \tag{A1.3a}$$

where x_r^u and x_r^v denote per capita consumptions, and welfare weights are equal to the product of the population numbers n_r^u, n_c^v and the inverse of individual marginal utilities of income λ_r^u and λ_c^v:

$$\alpha_r^u = n_r^u / \lambda_r^u \text{ and } \alpha_c^v = n_c^v / \lambda_c^v , \tag{A1.3b}$$

implying that individual consumers maximize the consumer surplus:

$$x_r^u = \arg\max_{x \geq 0} u_r^u (x) - \lambda_r^u p_r^u{}' x , \tag{A1.3c}$$

$$x_c^v = \arg\max_{x \geq 0} u_c^v (x) - \lambda_r^v p_c^v{}' x . \tag{A1.3d}$$

The general equilibrium model has a detailed component for agricultural production, which will be described further down. Here we simply represent this component by replacing the production function through a strictly quasiconvex transformation function $F_c(q_c, e_c) \le 0$, where q_c is the output and e_c the input vector.

This model also has a detailed exchange component in which production and input demand are given functions of prevailing prices at county level. These prices are obtained from regional selling and purchasing prices, $p_{rk}^{\bullet}$ and p_{rk}°, depending on whether the county is a net seller ($c \in C_{rk}^{\bullet}$) or a net buyer ($c \in C_{rk}^{\circ}$) of the product concerned. Now the county prices for outputs are determined as:

$$\breve{p}_{ck} = p_{rk}^{\bullet} - \breve{\kappa}_{ck} \text{ if } c \in C_{rk}^{\bullet} \text{ and } p_{rk}^{\circ} - \breve{\kappa}_{ck} \text{ otherwise,} \tag{A1.4a}$$

and for inputs as

$$\hat{p}_{ck} = p_{rk}^{\circ} + \hat{\kappa}_{ck} \text{ if } c \in C_{rk}^{\bullet} \text{ and } p_{rk}^{\circ} + \hat{\kappa}_{ck} \text{ otherwise,} \tag{A1.4b}$$

while the representative producer of county c solves:

$$\begin{aligned} \Pi_c(\breve{p}_c, \hat{p}_c) = \; & \max_{e_c, q_c \ge 0} \breve{p}_c' q_c - \hat{p}_c' e_c \\ & \text{subject to} \\ & \quad F_c(q_c, e_c) \le 0. \end{aligned} \tag{A1.4c}$$

Before turning to the producer model in more detail, we focus on the exchange part of the model, that deals with given input $\bar{e}_{rk}^{\bullet} = \sum_{c \in C_{rk}^{\bullet}} e_{ck}$, $\bar{e}_{rk}^{\circ} = \sum_{c \in C} e_{ck} - \bar{e}_{rk}^{\bullet}$, and output $\bar{q}_{rk}^{\bullet} = \sum_{c \in C_{rk}^{\bullet}} q_{ck}$, $\bar{q}_{rk}^{\circ} = \sum_{c \in C} q_{ck} - \bar{q}_{rk}^{\bullet}$, and similarly for endowments $\omega_{rk}^{\bullet}$ and ω_{rk}°. We represent demand by rural consumers at the regional, supposing that a fraction Γ_r (a diagonal matrix) of total consumption is from net purchasing rural counties. These fractions are only used to determine the processing requirements, and associated to these the price margins.

Regional tariffs $\xi_{rk}^{+}, \xi_{rk}^{-}$ and quotas $\bar{m}_{rk}^{+}, \bar{m}_{rk}^{-}$ on international trade, and other taxes on domestic trade can be incorporated by adding tariff terms $-\sum_r \sum_k (\xi_{rk}^{+} m_{rk}^{+} + \xi_{rk}^{-} m_{rk}^{-})$ in the objective function of the model and setting upper bounds on flows $m_{rk}^{+} \le \bar{m}_{rk}^{+}$, $m_{rk}^{-} \le \bar{m}_{rk}^{-}$, respectively. Indirect taxes and subsidies on consumption, production, or input use can be incorporated in a similar way (as in Ginsburgh and Keyzer, 1997, chapter 5). In addition, we also allow for lower bounds $\underline{m}_{rk}$ on exports, to represent export commitments. Hence, exports may co-exist with imports. Such commitments can also serve to address inevitable problems of heterogeneity of trade flows within a single commodity k. To sum up, the exchange component of the CHINAGRO welfare program reads:

$$V^* = \max_{v_{rr'} \ge 0;\; m_r^-, m_r^+, x_r^u, x_r^v \ge 0;\; z_r^-, z_r^+ \ge 0;\; g_r} \sum_r \alpha_r^u u_r^u\left(x_r^u\right) + \sum_r \alpha_r^v u_r^v\left(x_r^v\right) - \sum_r \left(\xi_r^{+\prime} m_r^+ + \xi_r^{-\prime} m_r^-\right)$$

subject to (A1.5)

$$\sum_i x_{ir} n_{ir} + \sum_{r'} v_{rr'} + g_r \delta^n + m_r^- + \bar{e}_r^{\bullet} + \bar{e}_r^{\circ}$$

$$= \sum_{r'} \frac{1}{1+\rho_{r'}} v_{r'r} + m_r^+ + \omega_r^u + \bar{q}_r^{\bullet} + \omega_r^{\bullet} + \bar{q}_r^{\circ} + \omega_r^{\circ} \qquad (p_r)$$

$$g_r = \sum_{r'} \theta_{rr'}' v_{rr'} + \tau_r^{+\prime} z_r^+ + \tau_r^{-\prime} z_r^- + \zeta_r^{+\prime} m_r^+ + \zeta_r^{-\prime} m_r^- + \bar{g}_r$$

$$\sum_r \left(\bar{p}_r^{+\prime} m_r^+ - \bar{p}_r^{-\prime} m_r^- \right) \le \bar{B} \qquad (\rho)$$

$$m_r^+ \le \overline{m}_r^+$$

$$\underline{m}_r^- \le m_r^- \le \overline{m}_r^-$$

$$\Gamma_r x_r^v + \bar{e}_r^{\circ} = \bar{q}_r^{\circ} + \omega_r^{\circ} + z_r^+ \qquad (p_r^{\circ})$$

$$(1-\Gamma_r) x_r^v + \bar{e}_r^{\bullet} + z_r^- = \bar{q}_r^{\bullet} + \omega_r^{\bullet}, \qquad (p_r^{\bullet})$$

where (A1.4) links the supply component to this exchange component. In the program (A1.5), δ^n is a vector with a unit entry in the row corresponding to the non-agricultural good.

In the welfare model, endogenous variables are (uncommitted) private consumption, intermediate deliveries to agriculture, and trade and transportation of agricultural products. The non-agricultural sector, which contributes the lion's share to the economy, is largely treated exogenously. A possible consequence is that scenarios treating $\bar{g}_r$ as given might generate gaps on the balance of payments, which could/should not be accommodated by agriculture. To avoid this, we allow for upward adjustment of non-agricultural consumption c_n, in regional shares η_r, with fixed marginal utility $\bar{p}_n = \bar{p}_n^+ = \bar{p}_n^-$ equal to the (Yuan) price of non-agriculture, because we can abstract from any taxes and transportation margins on non-agriculture given that these have been netted out in the exogenous demand $\bar{g}_r$. The variable c_n acts as a closure rule, and as long as it is positive in the optimum, maintains a unit value for the Lagrange multiplier ρ on the balance of payment constraint.

In summary, the complete general equilibrium model of the CHINAGRO project can now be written out, as follows, with the qualification that further details of the consumer demand and utility will be elaborated in the following section A1.2.

$$V^* = \max_{v_{rr'} \ge 0;\ m_r^-, m_r^+, x_r^u, x_r^v \ge 0;\ z_r^-, z_r^+ \ge 0;\ g_r} \sum_r \alpha_r^u u_r^u(x_r^u) + \sum_r \alpha_r^v u_r^v(x_r^v) - \sum_r \left(\xi_r^{+\prime} m_r^+ + \xi_r^{-\prime} m_r^- \right)$$

subject to (A1.6)

$$\sum_i x_{ir} n_{ir} + \sum_{r'} v_{rr'} + g_r \delta^n + m_r^- + \bar{e}_r^{\bullet} + \bar{e}_r^{\circ}$$

$$= \sum_{r'} \frac{1}{1+\rho_{r'}} v_{r'r} + m_r^+ + \omega_r^u + \bar{q}_r^{\bullet} + \omega_r^{\bullet} + \bar{q}_r^{\circ} + \omega_r^{\circ} \qquad (p_r)$$

$$g_r = \sum_{r'} \theta_{rr'}' v_{rr'} + \tau_r^{+\prime} z_r^+ + \tau_r^{-\prime} z_r^- + \zeta_r^{+\prime} m_r^+ + \zeta_r^{-\prime} m_r^- + \bar{g}_r + \eta_r c_n$$

$$\sum_r \left(\bar{p}_r^{+\prime} m_r^+ - \bar{p}_r^{-\prime} m_r^- \right) \le \bar{B} \qquad (\rho)$$

$$m_r^+ \le \overline{m}_r^+$$
$$\underline{m}_r^- \le m_r^- \le \overline{m}_r^-$$
$$\Gamma_r x_r^v + \overline{e}_r^\circ = \overline{q}_r^\circ + \omega_r^\circ + z_r^+ \qquad (p_r^\circ)$$
$$(1-\Gamma_r)x_r^v + \overline{e}_r^\bullet + z_r^- = \overline{q}_r^\bullet + \omega_r^\bullet, \qquad (p_r^\bullet)$$
$$e_r^\circ = \sum_{c\in C_r^\circ} e_c,\ q_r^\circ = \sum_{c\in C_r^\circ} q_c,\ e_r^\bullet = \sum_{c\in C_r^\bullet} e_c,\ q_r^\bullet = \sum_{c\in C_r^\bullet} q_c$$
$$F_c(q_c, e_c) \le 0.$$

Suppose that (i) the regional per capita consumer utility functions u_r^u and u_r^v are strictly concave, differentiable; (ii) the transformation functions F_c at county level are strictly quasi-convex, homogeneous, non-decreasing in $(q_c, -e_c)$; and (iii) total endowments support positive production of all goods. Then, it can be proven that for $\overline{B}$ sufficiently large, the welfare equilibrium of model (A1.6) exists, is unique, and once all distortions are eliminated, yields a Pareto efficient solution. The model generates bounded prices p_r and supports an equilibrium in which consumers maximize their surplus according to (A1.3c), (A1.3d) and producers maximize their profits according to (A1.4c).

A1.2. Accommodating switches between demand systems

The CHINAGRO welfare model is designed to simulate consumer demand behaviour over a prolonged period with significant economic growth. A key challenge in this connection is how to establish consistent linkages between different (and increasing) income levels and changing consumption patterns (consumer preferences). The existing literature typically employs projected or fine-tuned income elasticities, which are regarded as the most convenient link between demand system parameters and income development. However, inconsistencies can happen when projecting and fine-tuning income elasticities. The possible inconsistencies include violating “adding-up, symmetry, homogeneity, and non-negativity” conditions, infeasible marginal shares of expenditure, and constant Engel elasticity.

To avoid these inconsistencies, we have developed an extended linear expenditure system (LES) with switches and the corresponding simulation GAMS program to calibrate consistent demand systems for diverse income levels and growth rates. Although the direct utility function of this extended system does not have a closed-form expression, the indirect utility function of the system does have a closed-form expression and meets all conditions of consistency and budget constraints. In this consistent system, various expenditure shares and elasticities change significantly across the switching points of income. In this sub-section, we present the key specification of this demand system.

We distinguish G demand regimes indexed g, each characterized by an LES with committed consumption $\hat{c}_{kg}$ and Cobb-Douglas positive constant a_g and nonnegative exponents $b_{kg} = \gamma_g \hat{b}_{kg}$, such that $\sum_k \hat{b}_{kg} = 1$, and $0 < \gamma_g < 1$. The coefficients $\hat{b}_{kg}$ and $\hat{c}_{kg}$ are obtained from econometric estimation. In a model with a single regime and an expenditure level in excess of the committed consumption value, the coefficients a_g and γ_g are unobservable and irrelevant; but when multiple regimes and variable commitment values have to be accounted for, they can play a major role and their calibration becomes an issue.

Regime g is activated only once utility u rises above the regime-specific threshold $\underline{u}_g$. Once activated, a regime cannot be inactivated, i.e. it should never yield a utility below the threshold of the regime when it entered. Moreover, irrespective of whether utility falls above or below a particular threshold, feasibility should be maintained. For this, we introduce a scaling variable w_g on the unit interval that makes it possible to scale the commitment vector downwards. To avoid that such a regime yields higher utility the variable also scales down the utility of the regime concerned. The consumer program reads (the region subscript is dropped for ease of exposition):

$$
\begin{array}{lr}
\max_{x_k, u, c_{kg}, w_g \geq 0} u & \\
\text{subject to} & \text{(A1.7)} \\
w_g a_g \prod_k (c_{kg} / w_g)^{b_{kg}} + \underline{u}_g \geq u \qquad (\rho_g) & \\
c_{kg} \leq x_k - w_g \hat{c}_{kg} \qquad (\phi_g) & \\
w_g \leq 1 \qquad (\psi_g) & \\
\sum_k p_k x_k \leq \mu, \qquad (\lambda) &
\end{array}
$$

where μ is the total expenditure, c_{kg} the uncommitted demand. This is a convex, utility maximizing program with a standard budget constraint. It is feasible since all decision variables can be set to zero. Furthermore, because the first constraint is binding for at least one regime and the Cobb Douglas functions are strictly quasi-concave, consumption c is unique and a continuous function of prices and income. Finally, since all the constraints of the program have constant returns to scale, the valuation of the right-hand side constants exhausts the value of the objective: $u = \lambda\mu + \sum_g \psi_g + \sum_g \rho_g \underline{u}_g$, meaning that the part of the consumer surplus $u - \lambda\mu$ accruing to regime g is $\psi_g + \rho_g \underline{u}_g$. The idea is that for higher utilities the consumer surplus should mainly accrue to higher regimes, because this means that the consumer demand is mainly determined by them.

One special element in (A1.7) relates to the scaling. LES-demand theory usually abstains from interpreting commitments in utility terms. In (A1.7) we extend a Cobb-Douglas utility function with constant returns by an additional factor w_g on the unit interval, which is similar to what is known in production theory as the fixed factor. Commitments appear as input coefficients that produce this fixed factor via a Leontief technology with coefficients $\hat{c}_{kg}$. Consequently, utility derives from both committed and uncommitted demand. The scaling factor will be equal to unity as long as the consumer surplus, i.e. the rent of the fixed factor (in production terms, the profit of the utility producing firm), exceeds committed expenditure.

Another special element is the regime-specific bound on utility. If we disregard the scaling factor and set $\gamma_g = 1$, for ease of exposition, the relation between income and utility charts out at given prices a piecewise linear, concave relationship between total (commitment-inclusive) expenditure and utility, in accordance with:

$$(u - \underline{u}_g) \leq \lambda_g (\mu - \hat{\mu}_g), \qquad \text{(A1.8a)}$$

where marginal utility obeys

$$\lambda_g = a_g \frac{\prod_k (\hat{b}_{kg})^{\hat{b}_{kg}}}{\prod_k (p_k)^{\hat{b}_{kg}}} \tag{A1.8b}$$

which is taken to be falling with g, while committed expenditures are:

$$\hat{\mu}_g = \sum_k p_k \hat{c}_{kg} \ , \tag{A1.8c}$$

such that the intercept $\underline{u}_g - \lambda_g \hat{\mu}_g$ is rising. The marginal utility converts the uncommitted expenditure in (A1.8a) into utility metric, while the thresholds $\underline{u}_g$ refer to the utility of the commitment when fully realized ($w_g = 1$).

We will now incorporate the regime switches into the exchange component (A1.5). A subsequent extension to the full welfare model (A1.6) is straightforward. To do this, we distinguish in every region r six income groups indexed i, of which $i \in I^u$ are urban and $i \in I^v$ rural. Hence, we drop the superscripts u and v for consumption and utility.

$$V^* = \max_{v_{rr'} \geq 0;\ m_r^-, m_r^+, x_{ir} \geq 0;\ c_{irkg}, w_{irg} \geq 0;\ z_r^-, z_r^+ \geq 0;\ g_r, u_{ir}} \sum_r \sum_i \alpha_{ir} u_{ir} - \sum_r \left(\xi_r^{+\prime} m_r^+ + \xi_r^{-\prime} m_r^- \right)$$

subject to (A1.9)

$$w_{irg} a_{irg} \prod_k \left(c_{irkg} / w_{irg} \right)^{b_{irkg}} \geq u_{ir} - \underline{u}_{irg} \qquad (\rho_{irg})$$

$$c_{irkg} \leq x_{irk} - w_{irg} \hat{c}_{irkg} \qquad (\phi_{irkg})$$

$$w_{irg} \leq 1 \qquad (\psi_{irg})$$

$$\sum_i x_{ir} n_{ir} + \sum_{r'} v_{rr'} + g_r \delta^n + m_r^- + \overline{e}_r^{\bullet} + \overline{e}_r^{\circ} = \sum_{r'} \frac{1}{1+\rho_{r'}} v_{r'r} + m_r^+ + \omega_r^u + \overline{q}_r^{\bullet} + \omega_r^{\bullet} + \overline{q}_r^{\circ} + \omega_r^{\circ} \qquad (p_r)$$

$$g_r = \sum_{r'} \theta_{rr'}{}' v_{rr'} + \tau_r^{+\prime} z_r^+ + \tau_r^{-\prime} z_r^- + \zeta_r^{+\prime} m_r^+ + \zeta_r^{-\prime} m_r^- + \overline{g}_r$$

$$\sum_r \left(\overline{p}_r^{+\prime} m_r^+ - \overline{p}_r^{-\prime} m_r^- \right) \leq \overline{B} \qquad (\rho)$$

$$m_r^+ \leq \overline{m}_r^+$$

$$\underline{m}_r^- \leq m_r^- \leq \overline{m}_r^-$$

$$\Gamma_r \sum_{i \in I^v} x_{ir} n_i + \overline{e}_r^{\circ} = \overline{q}_r^{\circ} + \omega_r^{\circ} + z_r^+ \qquad (p_r^{\circ})$$

$$(1 - \Gamma_r) \sum_{i \in I^v} x_{ir} n_i + \overline{e}_r^{\bullet} + z_r^- = \overline{q}_r^{\bullet} + \omega_r^{\bullet}, \qquad (p_r^{\bullet})$$

A1.3. Specification of agricultural supply component and the closed-form solution

We recall the profit function (A1.4c) at county level, and disaggregate it further by distinguishing several land-use types, and run profit maximizations for every land-use type separately:

$$\Pi(\breve{p},\hat{p}) = \sum_j \max_{e_{kj}, q_{kj} \geq 0; L_j \geq 0} \sum_k \breve{p}_k q_{kj} - \sum_k \hat{p}_k e_{kj}$$

$$\text{subject to} \qquad \text{(A1.10)}$$

$$H_j(q_{1j},\cdots,q_{Kj},L_j,\overline{A}_j) - G_j(e_{1j},\cdots,e_{Kj},L_j,\overline{A}_j) \leq 0$$

$$\sum_j L_j \leq L,$$

where q_{kj} stands for the output product k from land use j and e_{kj} for the input. L_j is the labour applied to land-use type j and $\overline{A}_j$ the given number of capacity units in the forms of area, number of stable units, etc., depending on the land-use type. We impose separability between inputs and outputs in the transformation function $F_c(\cdots)$.

Land-use types fall in three classes with index set $J_p + J_g + J_o = J$, a price responsive class, grazing (its output is price responsive), and other land-use activities. We assume that the output function F_j is strictly quasi-convex, non-decreasing, and homogeneous of degree one; and that the input function G_j is strictly concave, non-decreasing and homogeneous.

For the price responsive class and grazing, the homogeneity property enables us to consider the aggregate output index y_j of every land-use type, and to solve (A1.10) in three parts, starting from the price or revenue index r_j:

$$r_j(\breve{p})y_j = max_{q_{kj} \geq 0} \sum_k \breve{p}_k q_{kj}$$

$$subject\ \ to \qquad \text{(A1.11)}$$

$$H_j(q_{1j},...,q_{Kj}) \leq y_j.$$

For given aggregate output y^j, by Gorman's rule, we can derive the profit maximizing supply of the separate crops as:

$$q_{kj}(\breve{p},y_j) = \frac{\partial r_j(\breve{p})}{\partial \breve{p}_k} y_j. \qquad \text{(A1.12)}$$

We suppose that revenue index is a *convex CES-function*.

$$r_j(\breve{p}) = \sum_h (a_{hj}(\breve{r}_{hj}(\breve{p}))^{\rho_j})^{\frac{1}{\rho_j}}, \qquad \text{(A1.13)}$$

for $\rho_j > 1$ and gross revenue from land-use type *j*, $\breve{r}_{hj}(\breve{p}) = \sum_k B^j_{kh}\breve{p}_k$ is non-negative, in which the matrix B^j transforms output commodity aggregates indexed *h* (e.g. milk cattle-meat cattle) into commodities (dairy, hides, meat), indexed *k*. Here the output price $\breve{p}_{ck}$ at county level is related to the market price $p^{\bullet}_{rk}$ and p°_{rk} of the corresponding region in (A1.9), according to price relationships (A1.4a and A1.4b) from region to county.

The revenue index (A1.13) is scale-independent and mainly serves as an aggregator over commodities. Next, we turn to the demand for inputs associated to the aggregate output. In principle the only requirement is that the cost function of all purchased inputs for given output y_j should be convex non-decreasing in y_j. However, to maintain a closed form solution we take the cost function to be piecewise linear in y_j, which allows for an arbitrarily fine approximation of more complicated nonlinear functions.

For simplicity of notation we now limit attention to a single purchased input, to be referred to as feed and purchased at the given price $p^f_j(\hat{p})$. In fact, the formulation could handle an arbitrary number of current inputs, complementary to y_j, and with a fixed purchasing price (vector) $\hat{p}$. The simplest way is to assume constant returns in input demand, by treating p^f_j as a concave differentiable unit cost function of input prices $\hat{p}$. In this case, the individual demands per unit y_j can be retrieved, by Shephard's Lemma as derivative of the cost function. The cost function defines the unit profit:

$$\tilde{\pi}_j(\breve{p}, p^f_j, y_j) = r_j(\breve{p})y_j - c_j(p^f_j, y_j), \qquad \text{(A1.14a)}$$

for piecewise linear cost function:

$$c_j(p^f_j, y_j) = min_{f_j \geq 0}\{p^f_j f_j \mid f_j \geq \eta^i_j y_j - \gamma^i_j, i = 1,...,M\}. \qquad \text{(A1.14b)}$$

where the coefficients η^i_j and γ^i_j are the fixed coefficients. Constraints that are never active have been dropped and the remaining ones through the maximization specify a piecewise linear cost function that is concave non-decreasing in prices, and convex non-decreasing in yield. These piecewise linear cost functions also define input demand functions in commodity terms:

$$e_{kj} = \frac{\partial p^f_j(\hat{p})}{\partial \hat{p}_k} f_j. \qquad \text{(A1.14c)}$$

It may be restrictive to assume a fixed composition of this purchased input but the chosen formulation has the advantage that it maintains continuity of the input demand curve. Nonetheless, extensions in which the input function p^f_j and its derivative to $\hat{p}$ depend on f_j as well can be envisaged.

The intercept γ_j^i makes it possible to represent through positive values, fixed or exogenous and free supply of the input as a given quantity (e.g., manure and natural soil fertility for crops, roughage and hay for ruminants, and household wastes as feed for pork and poultry). A switch point will occur once an additional input has to be purchased with rising output. This defines the indicator function:

$$i_j(y_j) = \{ i \in \{1,...,M\} \mid \hat{y}_j^i \leq y_j \leq \hat{y}_j^{i+1} \}, \tag{A1.15}$$

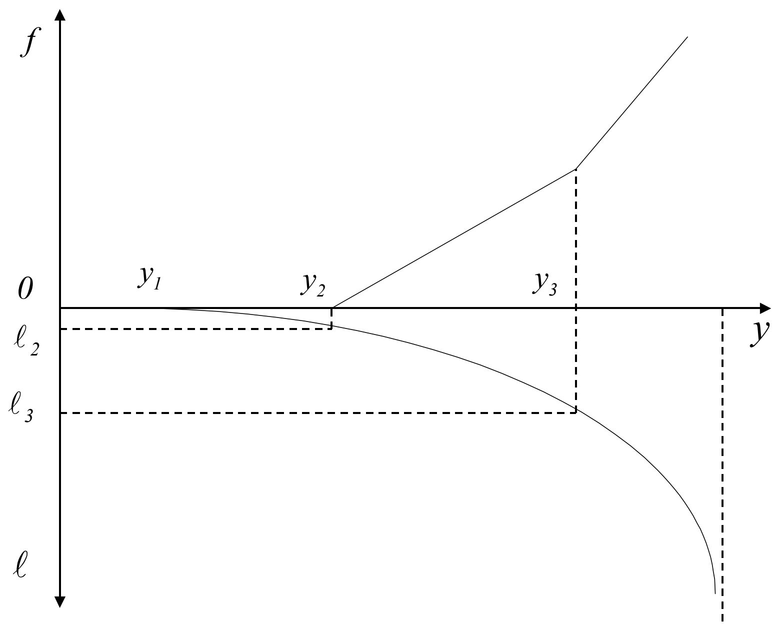
where $\hat{y}_j^1$ is the yield obtainable with zero feed and labour input. Consequently, in between switching points the unit profit has a constant derivative:

$$\pi_j^i = r_j(\breve{p}) - p_j^f \eta_j^i, \tag{A1.16}$$

with $\eta_j^i = 0$ for $i = 1$ denoting the marginal revenue in the regime that does not use any purchased feed.

The third step is to determine the aggregate outputs y_j. In the CHINAGRO welfare model, these are actually yields per unit of capacity in land-use type *j*. Capacity is measured respectively in hectares and stable units, depending on the land-use type. We formulate a profit maximization model by the representative farm, using a Mitscherlich-Baule yield function y_j, with given asymptote (yield potential) $\bar{y}_j$ and with labour as sole input. All other inputs are already dealt with as "feed" in (A1.14), i.e. fertilizer and manure for crops and purchased or locally available animal feed for livestock. We use a Mitscherlich-Baule production function because it has, like the logistic curve, an asymptote that can accommodate information on the yield potential of the land-use type in every county.

Figure A1.1. Two-level agricultural production function used at county level in supply component of the CHINAGRO welfare model.



The yield appears on the horizontal yield-axis. The level y_1 refers to the yield obtained without any formal labour (e.g., without bullock or tractor power and equipment); y_2 indicates the yield obtained with formal labour ℓ_2 but without purchased fertilizer (respectively purchased feed), i.e. with locally available manure and *night soil* (respectively with locally available crop and household residues and wastes); finally, y_3 refers to the yield-threshold beyond which fertilizer (respectively feed) use becomes less effective. The curve in the lower panel shows the response with decreasing returns to labour, and with the biophysical cropping potentials appearing on the right-hand side as a ceiling (asymptote). For extensive grazing a similar relationship is postulated but with the herd size rather than labour input as variable.

Let A_j denote the capacity use, $\bar{A}_j$ its positive availability per hectare or stable unit, hectare for short and ℓ_j the labour applied per hectare (equipped with implements). However, since for the land-use class grazing, the "harvesting labour" is essentially performed by the herds themselves and the stable-size (capacity) is given exogenously, the yield on grazing, with associated demand for supplementary feed, follows from there. Moreover, the labour of herders cannot be considered substitutable for that of cropping activities because of the large distances involved. Hence, we only consider labour allocation between the price responsive sectors, noting that the specification for grazing allows, nonetheless, for price response of the commodity bundle on the output side, following (A1.12).

Henceforth, we focus on the price responsive sectors $j \in J_p$. Labour is a local, non-tradable resource, and $\bar{L}$ is the fixed total labour available. The profit maximizing labour allocation meets a land and labour constraint and is obtained from:

$$\Pi = max_{A_j, y_j \geq 0} \{ \sum_j \tilde{\pi}_j(\breve{p}, p_j^f, y_j) A_j \mid \sum_j A_j \ell_j(y_j) \leq \bar{L}, A_j \leq \bar{A}_j \}. \tag{A1.17}$$

It remains to specify the labour requirement function $\ell_j(y_j)$. For this we use its inverse, the production functions $y_j(\ell_j)$. The yield potential $\bar{y}_j$ acts as an asymptote in the Mitscherlich-Baule production function:

$$y_j(\ell_j) = \bar{y}_j(1 - e^{\alpha_j - \beta_j \ell_j}), \tag{A1.18}$$

where we assume that $\beta_j > 0$ as additional output requires additional labour. This function is increasing and therefore has a continuous inverse, in closed form. Clearly, $\ell_j(y_j)$ is convex increasing. If for some land-use type, the net profit π_j remains positive for any y_j, all labour will be employed, and the marginal productivity or wage rate μ will be positive in the optimum. With this definition, program (A1.17) can be rewritten into:

$$\max_{A_j, \ell_j \geq 0} \sum_j \left(r_j(\breve{p}) \bar{y}_j \left(1 - e^{\alpha_j - \beta_j \ell_j}\right) - p_j^f \max\left(\max_i \left(\eta_j^i \bar{y}_j \left(1 - e^{\alpha_j - \beta_j \ell_j}\right) - \gamma_j^i\right), 0\right)\right) A_j$$

subject to (A1.19)

$$\sum_j \ell_j A_j \leq \bar{L} \qquad (\mu)$$
$$A_j \leq \bar{A}_j \qquad (\lambda_j)$$

To obtain the convex program associated to (A1.17), we rewrite the problem in aggregate variables, multiplying all per hectare variables by A_j, and substituting out the input requirement functions, as follows:

$$max_{A_j, F_j, L_j, Y_j \geq 0} \sum_j \left(r_j(\breve{p}) Y_j - p_j^f F_j \right) \tag{A1.20}$$
subject to

$$F_j \geq \eta_j^i Y_j - \gamma_j^i A_j \qquad (\theta_j^i)$$
$$\sum_j L_j \leq \bar{L} \qquad (\mu)$$
$$A_j \leq \bar{A}_j \qquad (\lambda_j)$$
$$Y_j \leq A_j \bar{y}_j (1 - e^{\alpha_j - \beta_j \frac{L_j}{A_j}}).$$

The first-order conditions are now:

(a) $\sum_j L_j \leq \bar{L} \quad \perp \quad \mu \geq 0$

(b) $A_j \leq \bar{A}_j \quad \perp \quad \lambda_j \geq 0$ (A1.21)

(c) $\beta_j (r_j(\breve{p}) - \sum_i \theta_j^i \eta_j^i)) \bar{y}_j \, e^{\alpha_j - \beta_j \frac{L_j}{A_j}} \leq \mu \quad \perp \quad L_j \geq 0$

(d) $p_j^f \geq \sum_i \theta_j^i \quad \perp \quad F_j \geq 0$

(e) $(r_j(\breve{p}) - \sum_i \theta_j^i \eta_j^i)(y_j - \beta_j \bar{y}_j \frac{L_j}{A_j} e^{\alpha_j - \beta_j \frac{L_j}{A_j}} - \sum_i \theta_j^i \gamma_j^i) \leq \lambda_j \quad \perp \quad A_j \geq 0.$

Suppose that r_j, $\bar{A}_j$, β_j, $\bar{L}$ and $\bar{y}_j$ are positive, and that $(\breve{p}, p^f, \bar{A}, \bar{L})$ are defined on a compact set *D*. Then, it is proven in Keyzer and van Veen (2005) that almost everywhere on *D*, the functions Y_j, input demand F_j and labour demand L_j and area A_j defined by (A1.20) are continuous in $(\breve{p}, p^f, \bar{A}, \bar{L})$.

Based on the above specification and with some plausible restrictions on parameters, the exact solutions can be obtained by a bisection algorithm with finite termination (Keyzer and van Veen, 2005).

References used in Appendix 1

Ginsburgh, V. and M.A. Keyzer (1997), "The Structure of Applied General Equilibrium Models", ISBN 0-262-07179-7. The MIT Press, Cambridge, Massachusetts and London, England.

Keyzer, M.A. and W. van Veen (2005). "Towards a Spatially Explicit Agricultural Policy Analysis for China: Specification of the CHINAGRO Models." CHINAGRO Working Paper, SOW-VU, Free University, Amsterdam, The Netherlands.

A1.4. List of main symbols in CHINAGRO welfare model

a_{irg}	constant of Cobb Douglas utility function;
a_{hj}	constant of output index
b_{irkg}	exponent of Cobb Douglas utility function
c_{ik}	uncommitted demand
c_j	unit cost
c	county index
d_h	total demand
e_c	input demand agriculture
f_j	fertilizer/feed input per hectare/stable unit
g_k	demand for transport input
g	regime of demand system
h	index for cropping activity
I	index line-segment fertilizer/feed demand
i	consumer group index
j	land use type index
k	commodity index
ℓ_j	labour per hectare/livestock unit
m_r^-, m_r^+	export, import of region r to/from foreign market
n_i	population of group i
$\breve{p}_k$	producer price
$\widehat{p}_k$	input price
p_f	fertilizer price
$\overline{p}_r^-, \overline{p}_r^+$	export, import price of region r to/from foreign market
r_j	gross revenue land use type j
$\breve{r}_{hj}$	gross revenue activity h land use type j
s	site index
u_i	utility of group i
u	superscript urban
$v_{kss'}$	flow from site s to s'
v	superscript rural/village
w_{ig}	weight on LES-demand regime g, group I
x_{ik}	consumer demand
y_j	yield land use type j
$\overline{y}_j$	yield potential type j

A_j	land/stable use of type j
$\overline{A}_j$	available land/stable capacity of type j
B^j_{kh}	output coefficient
$\overline{B}$	upper bound on trade deficit
B^+	loans
C_r	index set of counties in region r
F_c	transformation function agriculture
F_j	total fertilizer/feed use
G_j	input function agriculture
H_j	output function agriculture
I^u_r, I^v_r	index set of urban and rural population groups
L_j	labour use
T_s	transport cost function from s to its neighbours

α_i	welfare weight
α_j	intercept yield function
β_j	slope yield function
γ^i_j	intercept piecewise linear fertilizer/feed demand
$\tilde{\gamma}^i_{kj}$	intercept, commodity input requirement piecewise linear fertilizer/feed demand
$\varepsilon^-_{ig}, \varepsilon^+_{ig}$	deviation in calibration LES
η^i_j	slope piecewise linear fertilizer/feed demand
$\tilde{\eta}^i_{kj}$	commodity input requirement piecewise linear fertilizer/feed demand
$\widehat{\kappa}_{ck}, \breve{\kappa}_{ck}$	trade margin from urban regional to rural county market
κ	cost of foreign loan
λ_j	Lagrange multiplier on land
λ_g	Lagrange multiplier demand
μ_i	total expenditure of group i
μ	Lagrange multiplier on labour
ξ_k	producer tax
π_j	profit per land use type
ρ_s	physical loss factor
ρ_j	CES-output coefficient
ρ_{ig}	marginal utility g
τ^-_{rk}, τ^+_{rk}	input requirement for intra-regional transport
$\omega_{kc}, \omega_{kr}, \omega_{ks}$	endowment of commodity k

Appendix A.2. Data sets of CHINAGRO welfare model: Structure and composition[1]

A2.1. Introduction

The CHINAGRO project studies the development of China's food supply and feed availability, the growth of farm incomes and the changes in land use patterns in the next three decades. The project emphasizes the geographical variety of the country, as reflected by differences in land and livestock resources and prevailing farm technologies, as well as by differences in population pressure and non-agricultural income opportunities. Hence, the trade and transport cost structure of the country is a key element of the analysis which is, furthermore, conducted against the background of changing foreign trade conditions related to China's access to WTO, increasing concerns about water availability in the North and (uncertain) projections about future climate changes.

The central tool of analysis is a welfare-maximizing simulation model of the general equilibrium type. It distinguishes 2433 counties in which farm supply follows from optimal resource use, at the prevailing prices. Consumption, market clearing and non-farm supply are modelled at a more aggregated level, i.e. at the level of eight regions. The base year is 1997; the simulation period is the period 2003-2030. The model is fed by three data files, one with consumption and trade parameters, one with supply parameters and one with (alternative) scenario parameters. The data process starts with collecting basic information from various sources, brings the different components into CHINAGRO classifications, makes them consistent, fills gaps and produces the model input files. This Appendix describes structure and composition of the data set, as well as is its technical implementation and the input files for the model.

The data set covers the full economy, albeit with considerably more detail in agriculture than in non-agriculture. It distinguishes local and tradable commodities. Local commodities are traded only inside the own county, tradable commodities are traded everywhere. Prices and quantities are collected for both types of commodities. Since a general equilibrium model requires balanced accounting in prices and volumes, consistency of supply and demand volumes is explicitly imposed, as well as plausibility of price margins. Transaction values are calculated from prices and volumes. Obtaining a plausible picture of the value added of land use activities is an additional consistency requirement on prices and volumes. At the same time, the relation between agricultural resources (land, animals), intermediate inputs (feed, fertilizer), factor inputs (labour, power) and output (crops, meat, milk, eggs) should adequately reflect current cultivation practices in Chinese agriculture.

All data work is integrated in one consistent set of computer programs in GAMS. A modular set-up is followed. First, the source data are derived topic by topic, then they are integrated and finally the model input files are produced. This set-up allows for revisions of individual modules, without giving up the mutual links between the modules. Documentation of source data and explanation of calculations is added inside the programs themselves. This approach must be seen as an investment effort that facilitates maintenance and future updates of the CHINAGRO model.

[1] This appendix is based on van Veen et al., 2005

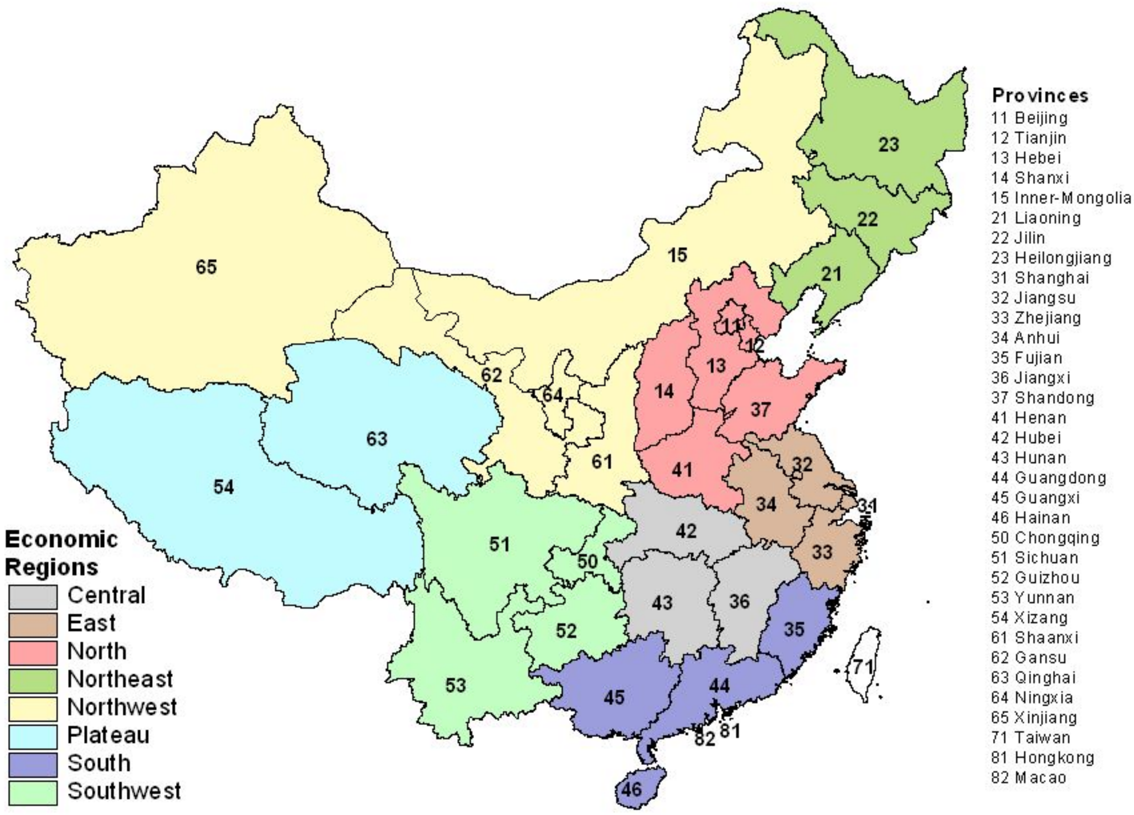
A2.2. Classifications

Here, the main classifications of the CHINAGRO model and data set are explained: regions (see 2.2a), supply activities, resources and land-use types (2.2b), tradable and local commodities (2.2c), and household classes (2.2d).

2.2a. Regional classification

The CHINAGRO model divides China into eight economic regions for which consumption, market clearing and non-farm supply are analyzed. Farm supply is modelled at detailed level, i.e., by county. Provinces are not explicitly distinguished in the model but they constitute an important intermediate geographical level in data collection (prices, cost-benefit in farming, feed structure) and scenario formulation. The 8 regions are shown in Figure A2.1.

Figure A2.1. Provinces of China and the eight regions in the CHINAGRO model



1. North	Beijing, Tianjin, Hebei, Shanxi, Shandong, Henan
2. Northeast	Liaoning, Jilin, Heilongjiang
3. East	Shanghai, Jiangsu, Zhejiang, Anhui
4. Central	Jiangxi, Hubei, Hunan
5. South	Fujian, Guangdong, Guangxi, Hainan
6. Southwest	Chongqing, Sichuan, Guizhou, Yunnan
7. Plateau	Tibet, Qinghai
8. Northwest	Inner Mongolia, Shaanxi, Gansu, Ningxia, Xinjiang

The 2433 counties that CHINAGRO distinguishes are defined administratively and divided as follows over the regions:

North	528 counties
Northeast	189 counties
East	251 counties
Central	277 counties
South	285 counties
Southwest	413 counties
Plateau	114 counties
Northwest	376 counties

2.2b. Supply activities, resources and land-use types

Farm supply is modelled at county level. Three cropping and six livestock land-use types are distinguished. Each of them has its own specific resource (land or herd). Together they compete for farm labour, which is assumed to be of one homogeneous kind. Each land-use type consists of several supply activities (types of crops or types of animals). Furthermore, five related supply activities are distinguished, viz. provision of grass, night soil, machinery services, household waste and greenfeed. Input and output consist of both tradable and local commodities. Inputs are considered by land-use type, outputs by activity.[2]

Off-farm supply is specified by region. Four activities are distinguished, each with its own input-output structure: fisheries, forestry, manufacturing and construction, services. Off-farm supply has only tradable input and output commodities (no local ones). Off-farm labour is not considered explicitly.

In total, the model has 32 supply activities, of which four are off-farm activities. They are listed in Table A2.1, together with the units in which the activity levels are expressed:

Table A2.1. Supply activities and their units of measurement[3]

Farm activities	
1. Paddy	(thousand metric ton)
2. Wheat	(thousand metric ton)
3. Maize	(thousand metric ton)
4. Minor grain crops	(thousand metric ton)
5. Roots and tubers	(thousand metric ton grain equivalent)
6. Soybean	(thousand metric ton)
7. Groundnuts	(thousand metric ton)
8. Oilseeds	(thousand metric ton)
9. Sugarcane	(thousand metric ton)
10. Sugar beets	(thousand metric ton)
11. Fruits	(thousand metric ton)

[2] In other words, the transformation functions in CHINAGRO's supply specification are separable.

[3] Product definitions follow the Yearbooks of the Statistical Bureau. They express roots and tubers in grain equivalent by taking 20% of the actual weight. Melons are included in vegetables and not in fruits. 'Other non-food crops' are mainly tobacco and hemp. With respect to cattle, the Statistical Bureau reports on total cattle, milk cattle and draught cattle. CHINAGRO defines the difference as meat cattle. Greenfeed consists both of green fodder and water plants used as feed. All livestock activity levels are expressed in terms of meat output, even when meat is not the main product of the activity. Standardized supply (for machine power, household waste, night soil, greenfeed and grass) is defined as supply at average provincial utilization rates, i.e. before taking into account county-specific variation in utilization rates.

12. Vegetables	(thousand metric ton)
13. Cotton	(thousand metric ton fibre)
14. Other non-food crops	(thousand metric ton)
15. Buffaloes	(thousand metric ton meat)
16. Draught cattle	(thousand metric ton meat)
17. Other draught animals	(thousand metric ton meat)
18. Milk cattle	(thousand metric ton meat)
19. Meat cattle	(thousand metric ton meat)
20. Sheep and goat	(thousand metric ton meat)
21. Yaks	(thousand metric ton meat)
22. Hogs	(thousand metric ton meat)
23. Poultry	(thousand metric ton meat)
24. Machine power	(thousand MWh, standardized)
25. Household waste	(thousand gigacal, standardized)
26. Household manure	(thousand metric ton nutrient, standardized)
27. Greenfeed	(thousand gigacal, standardized)
28. Utilizable grass	(thousand gigacal, standardized)
Non-farm activities	
29. Fisheries	(thousand metric ton)
30. Forestry	(ten million constant 1997 Yuan)
31. Industry and construction	(ten million constant 1997 Yuan)
32. Services	(ten million constant 1997 Yuan)

These activities belong to 16 supply types of which nine are farming (cropping or livestock) and five are related to farming. Two of them are non-farm supply types. Table A2.2 gives the list and the relation with the activities.

Table A2.2. Supply types and their activities

Land use types	
1. Irrigated cropping	all crops
2. Rain-fed cropping	all crops
3. Tree cropping	fruit
4. Draught animal system	buffaloes, draught cattle, other draught
5. Grazing system	milk cattle, meat cattle, sheep&goat, yaks
6. Traditional ruminant farming	milk cattle, meat cattle, sheep&goat
7. Specialized dairy farming	milk cattle
8. Traditional non-ruminant farming	pigs, poultry
9. Intensified non-ruminant farming	pigs, poultry
Supply types related to farming	
10. Machine power	machine power
11. Household waste	household waste
12. Household manure	household manure
13. Greenfeed	greenfeed
14. Utilizable grass	utilizable grass
Non-farm supply types	
15. Fish and forestry	fisheries, forestry
16. Non-agriculture	industry&construction, services

The model considers farm labour as homogeneous county resource for which all land-use types compete. The resources of the supply types related to farming have a diverse nature. Machine power and greenfeed have their own specific resource formulated as an ‘utilizable supply capacity’. Grass supply depends on the underlying natural and sown grassland resources, whereas household waste and night soil are related to the rural and urban population sizes.

2.2c. Commodity classification

Local commodities are traded only inside the county of production. For them there is merely intermediate demand, no final demand. Table A2.3 gives the list of the eight local commodities.

Table A2.3. Local commodities and their quantity units

1. Crop residues	(thousand gigacal)
2. Grass	(thousand gigacal)
3. Greenfeed	(thousand gigacal)
4. Household waste	(thousand gigacal)
5. Animal manure	(thousand metric ton nutrient)
6. Night soil	(thousand metric ton nutrient)
7. Animal power	(thousand mwh)
8. Machine power	(thousand mwh)

Tradable commodities are traded widely, both inside the region of production, across regions and from and to abroad. CHINAGRO distinguishes 17 tradable commodities. The emphasis is on food, with eight crop commodities, five livestock commodities and fish. Non-food (other than feed) is aggregated into one commodity. Furthermore, there are two feed commodities, apart from maize, which can be used both as food and as feed. The food content of meals eaten outside (on the street or in restaurants) is included in the basic food commodity. The same applies to the food content (grain, sugar, fruit) of alcoholic and non-alcoholic beverages. Table A2.4 gives the list of tradable commodities.

Table A2.4. Tradable commodities and their quantity units

1. Rice	(thousand metric ton milled)
2. Wheat	(thousand metric ton flour)
3. Maize	(thousand metric ton)
4. Other staple food	(thousand metric ton soybean equivalent)
5. Vegetable oil	(thousand metric ton)
6. Sugar	(thousand metric ton)
7. Fruits	(thousand metric ton)
8. Vegetables	(thousand metric ton)
9. Ruminant meat	(thousand metric ton)
10. Pork	(thousand metric ton)
11. Poultry meat	(thousand metric ton)
12. Milk	(thousand metric ton)
13. Eggs	(thousand metric ton)
14. Fish	(thousand metric ton)
15. Non-food excl feed	(ten million constant 1997 Yuan)
16. Carbohydrate feed	(thousand gigacal)
17. Protein feed	(thousand gigacal)

Each local or tradable commodity is produced by one or more of the activities listed earlier in Table A2.1. Conversely, each of the activities produces one or more of the local and tradable commodities. The mapping from activities to commodities incorporates several aspects, such as joint-ness of output, crop processing, distinction between food use and feed use (except for maize) and seed deduction.

The commodity 'other staple food' is an aggregate commodity that covers the shares of minor grains, roots, tubers, soybeans and groundnuts that are directly consumed as food. For feed the picture may be difficult to grasp. Maize is the only commodity, which covers both food and feed. All other commodities are either food or feed.[4] Together, there are seven feed commodities, four local ones and three tradable ones. Their contents are clarified further in Table A2.5.

Table A2.5. CHINAGRO classification of local feed and tradable feed

Local feeds:		
	crop residues	straw, husk, maize stem and leaves
	grass	fresh grass, hay
	greenfeed	green fodder, water plants
	household waste	residuals from household consumption
Tradable feeds:		
	maize	maize grain
	carbohydrate feed	minor and low-quality grain, tubers, vegetables feed, molasses
	protein feed	bran (from wheat and rice), cake (from soybean, peanuts, cottonseed and other oilseeds), fishmeal

2.2d. Household classification

Consumer demand is specified by region and for urban and rural separately. Furthermore, three classes (low, medium, high) are distinguished within urban respectively rural. Thus, we have in each region the following six household classes:

- rural low income
- rural middle income
- rural high income
- urban low income
- urban middle income
- urban high income

The definition of urban and rural areas follows the 2000 Population Census. The distinction between low, medium and high income is based on expenditure percentiles, hence not on a priori imposed income thresholds. In this way, the subclasses have equal population numbers in the base year.

A2.3. Structure of the CHINAGRO model data set

The structure of the data set follows the CHINAGRO model specification, described in Keyzer and van Veen (2005). Below, we discuss successively the core supply and demand information in the data set, the trade balances that link supply and demand, the price margins along the trade chain and the CHINAGRO Accounting Matrix in which transaction values and price margins are integrated. This accounting matrix shows the relations between

[4] When the output of crop activities (other than maize) is converted into supply of commodities, a distinction is made between food use and feed use.

commodity balances and income accounts in the same way as social accounting matrices usually do,[5] but is not really a 'social accounting' matrix since only consumption is distinguished by household class and not the income side. All classifications mentioned below have been explained in the previous section.

2.3a. Supply and demand data

On-farm supply data are specified by land-use type and county, and consist of:

. tradable commodity inputs and their prices,
. local commodity inputs and their prices,
. labour input and the wage rate,
. resource volumes (land, herds, other),
. activity levels and their output in terms of local and tradable commodities,
. farmgate prices of the output.

Off-farm supply data are specified by supply activity and region, and consist of:

. tradable commodity inputs and their prices,
. tradable commodity outputs and their prices.

Consumer demand data are specified by household class and region, and consist of:

. population,
. commodity consumption volumes and their prices.

Other final demand data are specified by region, and consist of:

. commodity demand for public consumption and its price,
. commodity demand for fixed investment and its price,
. commodity stock changes and their prices,
. commodity losses and their prices.

2.3b. Trade balances

The model distinguishes several trade flows between supply and demand locations. For local commodities the flows are simple: local commodities remain within the county of origin. Hence, in each county demand equals the utilized part of supply. For tradable commodities the flows are more comprehensive: they go across counties, across regions and from and to abroad. The structure of these flows is given in Figures A2.2 and A2.3.

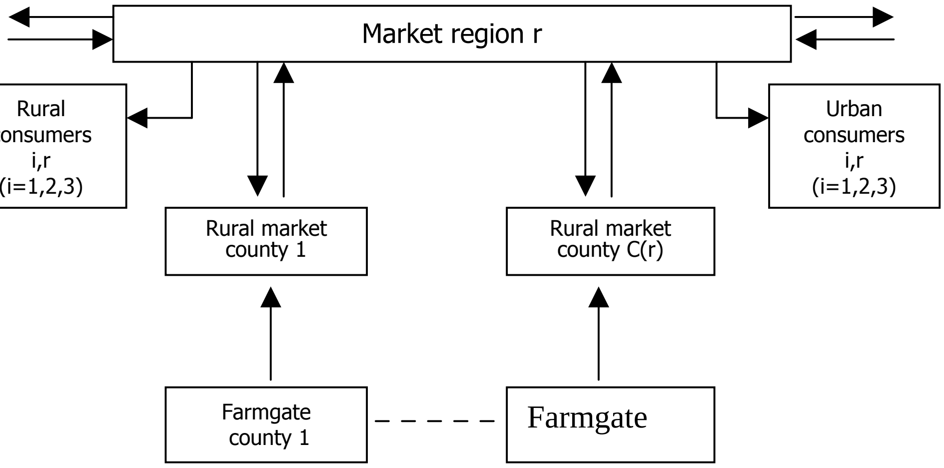
Figure A2.2 shows the flow of products from the farmgate in each county of region r via the rural county markets to the regional market, as well as the reverse flow of intermediate inputs that the farmer buys at the rural county markets. Furthermore, it shows the flows of consumer goods from the regional market rural and urban consumers. Final demand categories other than private consumption, as well as output and input of off-farm production are not shown explicitly since these transactions are assumed to take place at the regional market and valued at the regional market price.

The horizontal arrows in Figure A2.3 provide the link between region r and the other regions, as well as the link to abroad. These links are shown explicitly in Figure A2.3, represented as bilateral flows between adjacent regions. The figure allows for direct foreign trade flows in

[5] See e.g. Pyatt and Round (1985).

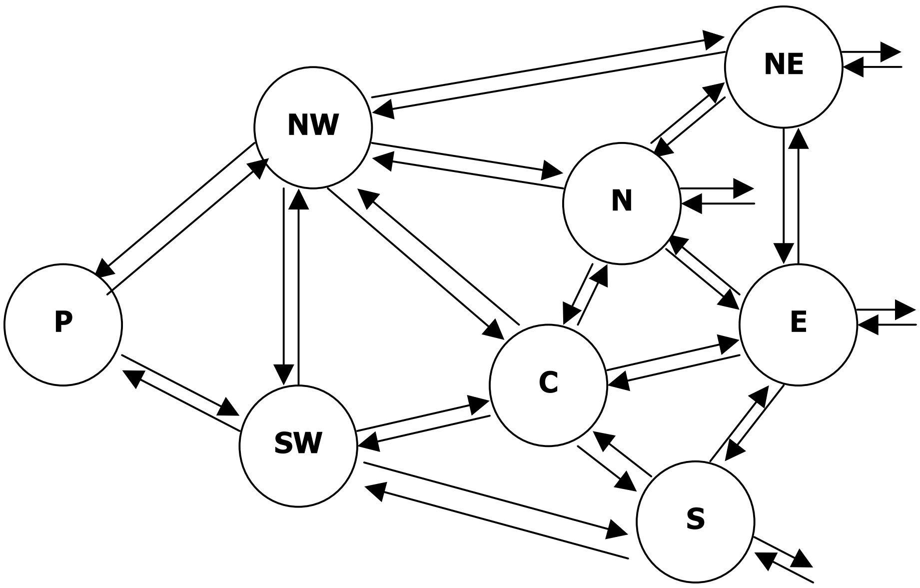
four of the eight regions (corresponding to the current implementation of the CHINAGRO model).

Figure A2.2. Trade flows inside the regions



with prices: regional market prices
consumer prices
county market prices
farmgate prices

Figure A2.3. Inter-regional and foreign trade flows



with prices: regional market prices
import c.i.f.
export f.o.b

Together, Figures A2.2 and A2.3 imply that for each tradable commodity the following balance holds, by region:

production + net inflow from other regions + net import from abroad =
intermediate use + consumption + investment + losses + net stock increase

2.3c. Price margins

Figures A2.2 and A2.3 point to different prices of the agricultural commodities, depending on their location and processing stage:

- farmgate price by county,
- rural market price by county,
- market price by region,
- consumer prices by household class and region,
- import c.i.f and export fob price by region.

The price differences are due to (i) trade, transport and processing (TTP) margins along the paths indicated by the arrows in the figures, and (ii) commodity taxes. CHINAGRO distinguishes four types of commodity taxes: producer tax, consumer tax, export tax and import tax.

When the direction of the trade flow is fixed (and the flow exists indeed) the relation between the corresponding price levels is clear. Thus, one has:

- farmgate price equals market price minus producer tax and TTP margin,[6]
- consumer price equals market price plus TTP margin and consumer tax.

When two directions are possible, as is the case for all interregional and foreign flows in Figure A2.3, the relation between the prices depends on the actual direction of the flow. These trade flows are determined endogenously in CHINAGRO. At most one direction per commodity is profitable at the same time. Also zero trade (autarky) is possible. Simultaneous import and export flows of the same commodity on the same path are only possible when one of the flows is imposed as committed flow.

The possibility of foreign trade in a region determines upper and lower bounds on the regional market price:

- the regional price is not higher than the import c.i.f. price plus import tariff and TTP margin,
- the regional price is not lower than the export f.o.b. price minus export tariff and TTP margin.

Inter-regional trade with neighbouring regions may further narrow these bounds. Interregional flows go from the region with the lowest price to the region with the highest price, as long as the TTP margin is not prohibitive. If so, the resulting price difference exactly covers the TTP costs. Otherwise, the price difference is less than the TTP margin.

[6] Since the geographical diversity within a region is quite large, the transport structure is hard to capture via single-path flows. Therefore, some negative TTP margins were accepted.

2.3d. CHINAGRO accounting matrix

The commodity flows can be expressed in values by using the appropriate prices. The resulting transaction values can be represented as accounts in the CHINAGRO Accounting Matrix, which is shown in Table A2.6. It uses the following index sets:[7]

c	counties
hn	non-farm supply activities
hs	farm (and related) supply activities
i	household classes
jn	non-farm supply types
js	farm (and related) supply types
k	tradable commodities
ka(k)	subset of tradable commodities except non-food
kl	local commodities
kpr(k)	non-food subset of tradable commodities
r	regions
tp	TTP paths
tx	commodity tax margins

The accounting matrix is square and has (K+JN*HN+2)*R + (KL+JS+1)*C + 2 rows and columns (indicating the number of elements of a set by the set name in capitals). Corresponding rows and columns add to the same total, thus constituting a balanced account. The (shaded) first row and column give the names of the accounts, while the sets indicate the classification. The items in the scheme are sub-matrices that follow the dimensions of the accounts.

The arguments added to each item do not refer to the dimension of the sub-matrix but represent the classification in which the essential information is obtained. This information may be more disaggregated than the account itself. In other words, the arguments of the sub-matrices may contain sets for which the accounts themselves are not distinguished separately (like the set i in the sub-matrix of consumption, the set hs in the sub-matrices of farm production, the set tp in the sub-matrix of commodity margins and the set tx in the sub-matrix of commodity taxes). Furthermore, the arguments of the sub-matrix of inter-regional trade show that these items are included as bilateral flows, and not merely as net flows by region.[8]

The *commodity accounts* have demand along the row and supply in the column. For local commodities there is only production and intermediate demand, for tradable commodities the accounts have several types of final and intermediate demand whereas the supply values come from three sources (other regions, abroad and production), augmented with TTP and tax margins. Interregional trade is measured at the market price of the receiving region. Investment covers both fixed investment and net stock increases. The *farm labour account* simply records the earnings by land-use type in each county and channels them, via the column, to the regional budget receipts.

[7] These set names (except tp and tx) are also used in the GAMS- programs.

[8] With the exception of non-food for which CHINAGRO has only the net outflow by region.

Table A2.6. CHINAGRO Accounting Matrix, in million Yuan, 1997

	Tradable commodities (k,r)	Local commodities (kl,c)	Farm labor (c)	Farm supply (land use) types (js,c)	Non-farm supply types (jn,hn,r)	Trade, transport and processing (r)	Regional budgets (r)	Transfers and finance	Balance of payments
Tradable commodities (k,r)	Interregional trade (k,r,r')			Intermediate demand (k,js,c)	Intermediate demand (k,jn,hn,r)	TTP demand (kpr,tp,r)	Consumption (k,i,r), public demand (kpr,r), investment (k,r) and losses (ka,r)		Export (k,r)
Local commodities (kl,c)				Intermediate demand (kl,js,c)					
Farm labor (c)				Labor remuneration (js,c)					
Farm supply (land use) types (js,c)	Production (k,js,hs,c)	Production (kl,js,hs,c)							
Non-farm supply types (jn,hn,r)	Production (k,jn,hn,r)								
Trade, transport and processing (r)	Agricultural commodity margins (ka,tp,c)								
Regional budgets (r)	Agricultural commodity taxes (ka,tx,c)		Farm wages (c)	Farm operating surplus (js,c)	Non-farm value added (jn,hn,r)				
Transfers and finance							Net transfers and net lending (r)		
Balance of payments	Import (k,r)							Net outflow to abroad	

The farm output values, by county and land-use type, are obtained by adding the elements on the rows of the *farm supply accounts*. The columns show the production structure in terms of local and tradable intermediate input values, labour payments and operating surplus. As mentioned earlier, farm output is distinguished by activity and land-use type, whereas inputs are shown at more aggregate level, i.e. by land-use type. The *non-farm supply accounts* have the same set-up, but without local and labour inputs. On the other hand, they are distinguished fully (on both input and output side) by activity and supply type.

The *trade, transport and processing account* is a special one. Its row records the value increase of agricultural commodities by TTP path, region and commodity. In the model these values increases are represented as input of non-food. The values of these inputs equal the value increases of the agricultural commodities, and are booked as TTP demand in the column of the account. In case of interregional trade the non-food input is assumed to be delivered by the region of origin.

Finally, there are the budget accounts. The *regional budget accounts* have the receipts along the row, and the expenditures in the column. The receipts consist of wages, operating surplus and taxes. The expenditures are the final demand categories. The sum of net transfers and net lending is the residual item for each region. CHINAGRO considers these payments neither bilaterally nor separately. The *transfer and finance account* simply shows that the sum of net regional outflows equals the national outflow to abroad. Also the *balance of payments* has the receipts along the row and the expenditures in the column, at least when one looks at it from the point of view of the foreigner. By definition, the ‘net outflow to abroad’ (the aggregate of all transfers, factor payments and capital transactions) equals the country’s trade surplus.

A2.4. Derivation of the data set

The construction of CHINAGRO’s base-year data set consists of three phases. First, data by topic are collected, scrutinized and reclassified. Then, they are integrated by making them consistent in terms of economy-wide balances and accounts. The economy-wide balances and accounts that CHINAGRO imposes have been explained in the previous section. However, in one aspect the data process does not directly follow this accounting structure: it focuses on provinces instead of counties when deriving the balances of the local commodities. Balances at county level are studied afterwards only. The three phases are discussed below.

2.4a. Main data sources

Here, the first phase of the construction process is summarized. The discussion follows the same division of topics as the actual implementation in the software. Below, the file names are added already between brackets, for later reference.

Crop farming (crops.gms)
Crop area is taken from the Ministry of Land and Resources. Crop output is obtained by combining information from the Ministry of Agriculture and the National Bureau of Statistics. Crop inputs are based on a detailed analysis of primary data by project partners IGSNRR, CAU and IIASA. Output and input prices (of local and tradable commodities) are derived from the farm cost-benefit accounts of the Bureau of Statistics. Area, output and input data are collected by county, prices by province. Crop processing coefficients that describe the transformation of crop output into main products and by-products, are partly from IIASA,

partly from FAO. Finally, the data are rearranged in CHINAGRO classifications and value added is calculated from the volumes and prices.

Livestock farming (livestock.gms)
Animal numbers and meat, milk and egg output are obtained by combining information from the Ministry of Agriculture and the National Bureau of Statistics. Feed inputs are based on a detailed analysis of primary data by project partners CCAP and IIASA. Slaughter rates, carcass weights and feed conversion ratios are calculated to test these input and output volumes. The remaining output and input data are derived from the farm cost-benefit accounts of the Bureau of Statistics. The latter also provide the output and input prices (of local and tradable commodities). All data are collected by province. Finally, they are rearranged in CHINAGRO classifications and value added is calculated from the volumes and prices.

Fisheries, green fodder (othersup.gms)
Provincial fish output volumes and values are taken from the China Statistical Yearbook of the National Bureau of Statistics. Producer prices are calculated residually. Provincial green fodder volumes can be found in the Rural Statistical Yearbook. Assumptions are made about its price and calorie content.

Non-agriculture (io.gms)
Non-agricultural data are, to a large extent, based on the Input-Output tables at regional level, originating from the Statistical Bureau and aggregated by IIASA. Adjustments are applied with respect to the treatment of trade and transport services and food processing, since the tables are expressed in producer prices whereas CHINAGRO operates in purchaser prices. Furthermore, the (missing) Plateau region is added, via assumptions about its input structure. The resulting tables provide the data source for the input and output volumes in the non-agricultural sectors and forestry, as well as for public demand and investment demand.

Population (pop.gms)
Urban and rural population figures are based on detailed analysis of primary data by IIASA and IGSNRR. The basic source is the 2000 Population Census, with a limited degree of upward adjustment for underreporting. Details can be found in Toth et al. (2003). Combination with earlier surveys leads to population data by county for model base year 1997. Provincial labour force data are derived from the China Statistical Yearbook. Furthermore, coefficients are specified, separately for rural and urban, for the calculation of household waste (for feed) and night soil (for manure).

Land resources (landwater.gms)
Grass land and its yield are based on detailed work of IIASA and IGSNRR. These figures are supplemented with data on forests and non-agricultural use of land resources such that, together with the crop areas mentioned above, full land balances are obtained. They are specified by province.

Import and export (foreign.gms)
Import and export volumes and prices of agricultural products are taken from FAO's Supply-Utilization Accounts (FAO, 2004) and rearranged in CHINAGRO classification. Non-agricultural import and export values are calculated as the difference between these agricultural values and the total trade values in the balance of payments of the China

Statistical Yearbook. Agricultural foreign trade is allocated to regions using trade flow information provided by CCAP.

Market prices (prices.gms)
At provincial level, urban and rural consumer prices are derived from the household survey of the Statistical Bureau. These prices provide a more complete overview than the market survey prices (available for a sample of 70 urban and 100 rural markets). The derivation imposes higher urban than rural prices. For some commodities price differences are assumed across the three household groups reflecting the fact that richer households buy higher quality, both within rural and within urban areas. The market price is defined as the price paid by the lowest rural household class. Regional prices are obtained by applying population weights. Then, together with the import c.i.f, the export f.o.b. and the farmgate prices derived earlier, the empirical set of tradable agricultural prices of Figures A2.2 and A2.3 is complete.[9] The non-agricultural price is determined (implicitly) by defining an appropriate volume unit in terms of constant 1997 Yuan. Since tax and trade and transportation costs are neglected for non-agriculture, its price is the same everywhere.

Private consumption (demand.gms)
Per caput consumer expenditures are derived by combining the household survey of the Statistical Bureau (especially its food budget shares) with the regional IO-tables. The resulting expenditures are reclassified into the commodities and household classes of CHINAGRO, by region.

Agricultural commodity taxes (tratax.gms)
Tax rates on agricultural commodities are based on CCAP-estimates. The specifications are the same throughout China, hence no regional differences. With respect to producer taxes, two rates are distinguished, one for grain and one for other commodities. Consumer taxes are very limited and represent the value added tax that is gradually being introduced. Export and import tariff rates cover both applied and implicit rates.

2.4b. Closing the accounts at regional and provincial level

In the second phase balanced accounts are derived, both in terms of volumes and in terms of values. The latter follow the scheme of the CHINAGRO Accounting Matrix of Table A2.6 but, as mentioned above, with provinces instead of counties. A second difference is that interregional trade flows are not calculated bilaterally. Instead, the data set confines itself to computing the net inflow from other regions. Deriving bilateral trade flows requires consistency with the regional price differences. It is done in a special calibration step, as part of the modelling software.

Above, in collecting the base-year data topic by topic, several consistency and plausibility checks are conducted already, both physically (land balances, input intensity in crop farming, feed conversion in livestock farming, input-output structure of non-agriculture) and financially (cost structure and value added by type of farming). Integrating the accounts consists essentially of an additional set of consistency checks, this time related to the use of data sources from different origins. These checks are made in file consist97.gms.

[9] The rural market price in Figure A2.2 is not defined as an empirically observable price and is constructed via specific model input coefficients.

Integrating the accounts (consist97.gms)
First, the calorie intake of the household classes is calculated by combining expenditure values, consumer prices and calorie coefficients (largely from FAO). Then, the margins between producer and market prices are assessed, as well as the margins between market and border prices. The feed demand mix is adjusted by a stepwise two-dimensional scaling procedure to make it consistent with the supply of the various types of feed, while maintaining the same level of energy intake by animal. Finally, the commodity volume accounts are closed, primarily by calculating nationwide stock changes. In case of implausible human calorie intakes, price margins, feed mix scaling factors or stock changes, adjustments are made 'upstream', i.e. in the data files of the first phase.
In fact, closing the commodity volume accounts goes together with determination of the values of the CHINAGRO Accounting Matrix. The process is summarized in Textbox A2.1. The resulting data set is summarized in the tables of the Appendix. In these tables, the local commodities are valued at the price which they have in the data set. This price is lower than its tradable equivalent (in terms of calorie or nutrient content), due to handling costs.[10] Furthermore, in presenting value added of farming, the earnings of the 'related' activities (collection of household waste and household manure, machine power services, provision of greenfeed, herd tending and hay collection) is included in the value added of the cropping and livestock sectors.

2.4c. Balances at county level (supdat97.gms)
In the third phase the county data set of farming is extended, in file supdat97.gms. The extension applies to resources and volumes only. Farmgate prices remain at provincial level. Since population and cropland, as well as cropping activities and their inputs, were already built up from county figures in the first phase, the essential remaining part on the supply side is the allocation of provincial herd sizes to counties, by activity (kind of animal) and land use (management type). It is done in a two-dimensional scaling procedure, using data tables compiled by IIASA from basic information of the Ministry of Agriculture and the National Bureau of Statistics. Furthermore, provincial grassland areas are distributed over the counties, with data from the same institutes.

The input by type of livestock activity in each county is calculated initially from the herd sizes, assuming the same production structure inside a province. Similarly, the tradable commodity output follows from the cropping and livestock activities by applying the same conversion factors to all counties in a province. However, for the output of local feed, manure and power differences are allowed, viz. in the utilization rates across counties. When demand in a county is relatively high compared to supply, the utilization rate is assumed to exceed the average provincial rate (albeit with an upper bound) and when demand is relatively low, the utilization rate falls below the average. Furthermore, the feed input packages in a county are allowed to deviate from the average provincial structure by shifting demand, within certain bounds, between tradable and local commodities and among local commodities. Similar adjustments are applied to the initial fertilizer inputs.

[10] In this respect the model is different: the model measures the price of the local commodity at the location of application (hence, after handling) and gets, therefore, equality with the price of the tradable equivalent.

Box A2.1. Steps in closing the CHINAGRO Accounting Matrix

1a. *agricultural tradable commodities, volumes:*
losses are specified by assumption, national stock changes are calculated residually and divided over the regions by assumption, net interregional trade is the closing item

1b. *agricultural tradable commodities, values:*
balanced accounts are automatically obtained if (i) the relevant price (producer, market, consumer, import, export) is applied to each item of the volume balance, and (ii) tax and TTP values are calculated from the corresponding price differences

2a. *non-agricultural tradable commodities, volumes:*
TTP demand is calculated from the agricultural TTP values and the non-food price, national stock changes are calculated residually and divided over the regions by assumption, net interregional trade is the closing item

2b. *non-agricultural tradable commodities, values:*
balanced accounts are automatically obtained from the volume balances since non-food has only one price

3a. *local commodities, volumes:*
by construction, supply is not less than demand; for most commodities supply and demand are even equal; if not, the unused local surplus is calculated residually

3b. *local commodities, values:*
balanced accounts are automatically obtained from the volume balances since the same price is applied to supply and demand (no TTP on local commodities) and the unused local surplus gets value zero

4. *farm labour:*
these accounts are balanced by definition, since the column element is just obtained as the sum of the row elements; the latter are calculated as the product of labour volume and wage rate

5. *farm supply types:*
operating surplus is calculated residually

6. *non-farm supply types:*
value added is calculated residually

7. *trade, transport and processing:*
the balance is obtained automatically by the determination of TTP demand (mentioned above under 2a)

8. *regional budgets:*
'net transfers and net lending' is calculated residually for each region

9. *transfers and finance:*
this account is balanced automatically since the net outflow to abroad is calculated as the sum of the net regional outflows

10. *balance of payments:*
this equality (net outflow to abroad equals trade surplus) must be satisfied if all other value accounts are balanced; hence, it can be used as check

A2.5. Model input files

The CHINAGRO model is formulated as a nationwide welfare programme with county-specific feedback components. In the welfare programme, consumption and trade decisions are modelled for all regional household classes simultaneously such that social welfare is maximized. In the feedback components, farm supply decisions maximize value added from farming in each county. In the welfare programme the output levels of farming are given, in the feedback components the regional market prices are given. Welfare programme and feedback components are solved iteratively, until convergence is obtained of the parameters (farm output, market prices) that they transmit to each other.

The organisation of the base-year model input follows the distinction between welfare programme and feedback module. Thus, these parts have their own input file, with base-year exogenous variables and coefficients. A third input file has time-series of exogenous variables and coefficients. This file always has the same structure, but its numerical content differs by model scenario. Below, the three input files will be discussed briefly.

Apart from exogenous variables and coefficients, the base-year input files also have data for model calibration. Model calibration is the determination of coefficients of an optimizing model such that the optimal outcomes reproduce a well-defined set of (base-year) observations. Calibration procedures usually operate via the first-order conditions and introduce a 'fixed effect' for each argument of the optimizing model. Since calibration of the CHINAGRO model is rather complicated, it is not done as part of the compilation of the data set but as part of the modelling software, separately for the welfare programme (exchange calibration) and the feedback components (supply calibration).

Naturally, the coefficients correspond to the functional specifications in the model. With respect to private consumption, CHINAGRO follows an extended linear expenditure system (LES). This extended system has several regimes, each represented by a standard LES and reflecting a different 'consumption style', from which the household endogenously selects the most optimal combination, given its level of total expenditures. The other final demand categories (fixed investment, public consumption, stock changes, food losses) are specified exogenously. Also non-farm supply is exogenous, with fixed input-output coefficients.

With respect to farm supply, the land use types have their own specific resource and compete with each other for farm labour, the common resource. The effect of input use is not activity-specific: input use determines aggregate output and, separately, aggregate output is allocated to activities.[11] The relation between input and aggregate output has two branches: (i) a Mitscherlich-Baule relation in which the ratio of actual to potential yield depends on labour input, at given use of machine and animal power, (ii) a piecewise linear relation between tradable fertilizer or feed inputs and aggregate output, at given use of local manure or local feed. The realized aggregate output is the minimum of the two branches (hence, no substitution between, on one hand, power and, on the other hand, feed or fertilizer). The activity mix follows a specification with constant elasticities of substitution (CES). Finally, there is a matrix with fixed mapping factors from activity to tradable commodity. This matrix covers joint outputs, food processing, seed deduction, feed use of primary crops (except for maize) and unit conversion.

[11] This representation does not apply to all land use types: tree cropping, draught animals and traditional ruminants are modelled exogenously, with fixed input and output coefficients.

Input file excinp97.gms

The input file for the welfare program (excinp97.gms) covers the fields of final demand (consumption, investment), non-farm production, interregional trade and foreign trade. The input data are specified by region, or nationally. Its main contents can be summarized as follows:

Exogenous base-year variables:	import c.i.f and export f.o.b prices, trade surplus of the country, non-farm production volumes, investment volumes, public consumption
Exogenous base-year policy parameters:	import, export and consumer tax rates
Coefficients:	input-output coefficients in non-farming, TTP coefficients between markets and border, interregional TTP coefficients, TTP coefficients from market to consumer, parameters of the LES branches (commitments and marginal expenditure shares)
Calibration data:	base-year regional market prices, base-year consumption volumes, sample of expenditure and price 'observations' and the regime/branch to which they belong

In the exchange calibration process of the model the TTP coefficients (especially, the inter-regional ones) will be revised and the specification of the demand system will be completed with the parameters that fit the LES branches together.

Input file supinp97.gms

The input file for the feedback components (supinp97.gms) covers the fields of farm supply and intraregional trade. Most input data are specified by county. Some coefficients are specified by province, meaning that they apply to each county in the province. Its main contents can be summarized as follows:

Exogenous base-year variables:	cropland, grassland, herd sizes, farm labour, agricultural machinery, population
Exogenous base-year policy parameters:	producer tax rates
Coefficients:	potential crop and livestock yields, grass yields, supply coefficients of household waste and night soil, coefficients of local commodity use, conversion factors from activities to commodities, TTP coefficients from producer to regional market
Calibration data:	base-year labour volumes by land-use type, base-year aggregate output by land-use type, base-year tradable inputs by land-use type, base-year activity levels by land-use type

In the supply calibration process of the model (which, in fact, is more than calibration and includes also cross-section estimation) the full specification of the Mitscherlich-Baule input functions, the piecewise linear input functions and the CES activity mix functions will be determined.

Input file baserun.gms
The input file for the base scenario (baserun.gms) sets the standard for the structure of all scenario input files. Its contents covers the 'data-intensive' part of the specification of the model scenarios. In the model software it is supplemented with straightforward assumptions about e.g. technical progress. The data on baserun.gms are specified nationally, by region or by province. In the latter case they apply to each county in the province. County-specific scenarios are not considered. Its main contents can be summarized as follows:

Trends on base scenario input file:	population (due to natural growth and migration),
	foreign trade prices,
	trade surplus,
	cropland,
	grassland,
	herd sizes,
	non-farm output,
	investment,
	public consumption,
	commodity tax rates

The data on the scenario files are specified for the base year 1997, the year 2003 (observed) and the years 2010, 2020 and 2030. They have been formulated in a joint effort of all project partners. IIASA, IGSNRR and CAU focused on the resource side and CCAP on trade prices, tax policies and non-agriculture, whereas SOW-VU converted the information of the other partners into full-blown model scenarios.

Finally, it should be mentioned that the descriptions above merely give the main content of the input files. For the precise coverage of the files, as well as the extraction of the information from the base-year data set, one should consult the CHINAGRO data programme. This programme consists of a sequence of GAMS files with computer statements and ample explanatory comments.

A2.6. Comments on data work

The data set presented in this report gradually developed over the period July 2001-December 2004, with contributions by several project participants. With respect to non-agriculture, the data set largely follows the existing input-output tables. Non-agriculture remains rather aggregate in the CHINAGRO model (although it dominates GDP) and the project made relatively few own consistency checks of non-agricultural data. Therefore, this evaluation focuses on the quantification of economic relations inside agriculture and food supply. In this field much data material appears to be available. On several subjects a choice between sources had to be made. Even when assumptions were necessary to fill gaps in the data set, there was always some kind of reference material that could be used to make an 'informed guess'.

If we consider the Supply Utilization Accounts of FAO as standard for the existing food balance sheets of China (the Chinese National Bureau of Statistics does not publish its own food balance sheets), we find a few substantial deviations in the CHINAGRO data set. These deviations can be traced only at national level since FAO does not look at regional balances. A general remark about these differences is that the CHINAGRO food balances are obtained from reconciliation of independent estimates of supply and demand (the latter calculated from household survey expenditures and prices), whereas it is not sure how 'independent' the FAO estimates on the consumption side are.

In addition to food balances, the data set attributes a central role to feed balances. Seven types of feed are distinguished, three tradable and four local ones. The construction of the feed balances may be considered as the most difficult part of the work. In several rounds of revision the assumptions on the supply side have been adjusted in order to generate sufficient feed, given the number of animals and their requirements. First, the balances are constructed at provincial level, and then, for local feed, the provincial balances are reduced to county balances. In fact, this order is illogic (better to go from county balances to provincial balances) but it is followed since information on feed input relations and supply utilization rates are available at provincial level. County-specific deviations from these provincial standards are allowed, within bounds, but are not sufficient to close all gaps. Therefore, at county level an implicit 'unexplained factor' or 'additional feed source' must be introduced. On average, it covers about 10 % of local feed demand. Part of the problem is caused by the fact that county allocations of crops, livestock, grass and population are not always fully consistent with each other. Implausible combinations may prevail in some counties, leading to large surpluses or deficits of local commodities. This issue is a point for improvement.

The third topic that has required a lot of effort is the compilation of the set of provincial prices, especially the margins between farmgate and market prices, and between market and consumer prices. Available data sources are cost-benefit statistics, market surveys and household surveys. In the end, the market surveys have not been not used, since the household surveys are assumed to be more representative for our purposes, and the regional market price has been defined as the lowest rural consumer price. Especially for fruits, vegetables and fish the prices of the household survey are considerably lower than the prices of the market surveys.

Farm incomes are calculated residually, by type of farming, from output and input volumes and prices, hence as the result of combining several different sources. The cost-benefit statistics (measured per area or animal unit) are used as benchmark figures but it is not sure whether they are really representative for all types of farm management. The resulting value added of cropping seems to be in line with the GDP figures of the National Statistical Bureau. In the livestock sector pork and poultry production comes out quite profitable (possibly a little too profitable for the intensive type), whereas for traditionally raised meat ruminants the picture is rather negative. In data terms, this problem is caused by rather low consumer expenditures for beef and mutton, due to either a low consumer price or a low consumption volume. Consistency between demand and supply side leads then, in both cases, to low farm revenues, which turn out to be even negative in some provinces. The representation of traditional ruminant meat production seems to be another point for revision, but how to go about it is not immediately clear, since also Ma et al. (2004) report a rather low beef output.

This issue is particularly troublesome also from the point of view of model calibration: in optimization one does not want to engage in a non-profitable activity!

Given this discussion, one can hardly claim that a data set like the one developed for CHINAGRO is ever a finished product. It is precisely for this reason that the data program has been fully computerized in a modular way. If certain basic data changes are considered necessary, the integration with the other parts can be tested automatically, whereas the contents of the input files for the model are adjusted right away. The system will also prove useful when one will decide to change the base year of the model, and possibly its classifications or the specification of a module. The exercise must then be redone but one can maintain the set-up and update or revise the files one by one.

To conclude, data work for an applied general equilibrium model is a laborious effort that cannot be justified fully if the model is used for a 'one-time' exercise only. Instead, the construction of the data set should be seen as an investment effort, together with the model, and treated in that way.

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Appendix A.3. Summary tables of CHINAGRO base-year data set

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List of Tables

=== Chinagro's main data tables for base year 1997 ==============

Commodity balances in volumes

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Milled rice (E+3 Mt) ==									
Production excl seed & waste	120820.14	3780.44	9767.39	27838.99	35813.96	22627.26	19279.58	3.16	1709.35
Private consumption	120389.18	6287.89	8536.99	23399.03	26654.66	27035.94	25661.92	130.15	2682.59
Net export	548.07	-2503.79	1239.87	4466.94	9194.02	-4386.74	-6363.66	-126.98	-971.58
Net stock increase	-117.11	-3.66	-9.47	-26.98	-34.71	-21.93	-18.69	0.00	-1.66
== Wheat flour (E+3 Mt) ==									
Production excl seed & waste	78032.75	40929.99	2518.41	13369.27	3079.81	174.74	6407.73	674.70	10878.08
Private consumption	77943.73	41236.94	4159.69	9267.21	2356.19	2212.81	4625.34	961.48	13124.06
Net export	-998.65	-877.45	-1676.39	3915.72	680.69	-2040.51	1693.07	-296.19	-2397.60
Net stock increase	1087.66	570.51	35.10	186.35	42.93	2.44	89.31	9.40	151.62
== Maize (E+3 Mt) ==									
Production excl seed & waste	96132.26	31862.71	28515.82	4531.02	2265.97	2116.69	13052.13	23.49	13764.45
Private consumption	16360.75	5747.00	3123.29	1048.93	674.57	786.71	3467.73	0.98	1511.53
Intermediate use	79255.85	21123.24	7184.13	6091.75	6441.32	8772.61	26090.68	544.13	3007.98
Net export	6684.88	7037.24	20038.37	-2318.90	-4704.51	-7306.79	-15668.68	-520.12	10128.26
Net stock increase	-6169.22	-2044.77	-1829.98	-290.77	-145.42	-135.84	-837.61	-1.51	-883.32
== Other staple food (E+3 Mt) ==									
Production excl seed & waste	19215.67	5570.08	1861.37	2405.95	1731.12	2393.73	3572.37	116.58	1564.48
Private consumption	20454.48	5330.14	2216.36	3386.01	2405.67	2615.59	2420.84	297.93	1781.93
Net export	-483.24	458.96	-281.81	-885.46	-606.48	-127.74	1292.00	-176.77	-155.94
Net stock increase	-755.57	-219.02	-73.19	-94.60	-68.07	-94.12	-140.47	-4.58	-61.52

Commodity balances in volumes (continued)

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Vegetable oil (E+3 Mt) ==									
Production excl waste	8643.70	2259.82	711.49	1627.74	1659.46	449.41	824.55	70.81	1040.42
Private consumption	10566.42	2515.62	936.35	2061.32	1692.58	1245.91	1246.67	52.14	815.83
Net export	-2280.99	-349.47	-254.36	-501.04	-101.90	-815.12	-456.29	15.73	181.47
Net stock increase	358.27	93.67	29.49	67.47	68.78	18.63	34.18	2.93	43.12
== Sugar (E+3 Mt) ==									
Production excl seed & waste	7014.73	74.23	424.88	80.70	364.28	4137.65	1201.62	0.02	731.36
Private consumption	7074.87	1577.93	406.64	1608.45	794.31	1276.15	965.85	34.41	411.13
Net export	-361.58	-1506.89	-0.03	-1531.21	-445.69	2683.70	184.13	-34.40	288.80
Net stock increase	301.43	3.19	18.26	3.47	15.65	177.80	51.64	0.00	31.43
== Fruits (E+3 Mt) ==									
Production excl seed & waste	51300.26	18210.11	3147.91	5027.19	3971.30	11754.26	3345.67	19.85	5823.97
Private consumption	52088.43	15603.99	5511.82	10971.50	6106.71	4886.26	4480.92	266.08	4261.16
Net export	192.16	2954.12	-2303.75	-5848.24	-2059.52	7092.62	-1071.32	-245.84	1674.11
Net stock increase	-980.34	-347.99	-60.16	-96.07	-75.89	-224.62	-63.94	-0.38	-111.30
== Vegetables (E+3 Mt) ==									
Production excl seed & waste	195045.68	57191.40	18323.14	29432.94	27687.66	24223.83	25645.23	380.09	12161.39
Private consumption	189349.45	52847.54	20839.56	25450.18	23241.29	23512.43	29615.08	976.82	12866.56
Net export	2033.02	3269.74	-2860.55	3429.97	3926.35	256.44	-4451.50	-603.86	-933.57
Net stock increase	3663.20	1074.13	344.13	552.79	520.01	454.95	481.65	7.14	228.41
== Ruminant meat (E+3 Mt) ==									
Production excl waste	4331.31	1462.65	505.22	348.97	272.45	173.87	392.39	207.82	967.95
Private consumption	4043.36	1049.76	651.32	513.50	316.78	395.39	316.11	100.33	700.17
Net export	81.50	343.18	-170.19	-181.16	-57.31	-229.81	57.58	97.58	221.64
Net stock increase	206.44	69.71	24.08	16.63	12.99	8.29	18.70	9.91	46.14

Commodity balances in volumes (continued)

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Pork (E+3 Mt) ==									
Production excl waste	27831.68	4921.22	1944.47	3645.35	5246.80	3957.42	6594.72	60.72	1460.98
Private consumption	27788.89	5199.54	1992.23	4793.90	3698.39	4597.59	5994.52	84.93	1427.78
Net export	317.17	-229.81	-28.60	-1112.61	1600.14	-601.16	665.21	-23.61	47.61
Net stock increase	-274.37	-48.51	-19.17	-35.94	-51.72	-39.01	-65.01	-0.60	-14.40
== Poultry meat (E+3 Mt) ==									
Production excl waste	6296.98	1698.72	948.79	1134.87	401.68	1176.45	788.56	1.23	146.69
Private consumption	6474.40	1244.80	427.97	1509.09	658.75	1640.93	731.32	6.63	254.93
Net export	216.09	560.07	580.11	-303.30	-231.97	-390.96	106.52	-5.32	-99.07
Net stock increase	-393.51	-106.16	-59.29	-70.92	-25.10	-73.52	-49.28	-0.08	-9.17
== Milk (E+3 Mt) ==									
Production excl waste	9525.68	1837.22	1700.18	694.77	516.78	728.04	1112.93	675.96	2259.81
Private consumption	9561.58	2493.26	1067.99	2765.36	550.20	791.80	721.79	174.99	996.19
Net export	-5.36	-650.16	637.64	-2068.36	-31.76	-61.43	394.71	503.13	1270.86
Net stock increase	-30.54	-5.89	-5.45	-2.23	-1.66	-2.33	-3.57	-2.17	-7.24
== Eggs (E+3 Mt) ==									
Production excl seed & waste	12108.34	5196.42	1616.30	1999.60	756.00	664.01	1076.43	12.60	786.98
Private consumption	12153.19	4353.32	1410.38	2337.54	1219.93	1188.25	919.68	27.57	696.52
Net export	60.42	888.28	219.97	-320.56	-457.35	-518.46	166.11	-14.86	97.30
Net stock increase	-105.27	-45.18	-14.05	-17.38	-6.57	-5.77	-9.36	-0.11	-6.84
== Fish (E+3 Mt) ==									
Production excl waste	18594.83	3853.56	1636.17	5216.96	2505.03	4591.75	622.17	3.15	166.05
Private consumption	17322.56	3106.32	1424.05	5303.41	2075.67	3871.12	998.26	24.12	519.60
Net export	1236.97	739.92	209.01	-96.36	424.61	711.91	-377.28	-20.98	-353.87
Net stock increase	35.30	7.32	3.11	9.90	4.76	8.72	1.18	0.01	0.32

Commodity balances in volumes (continued)

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Non-food excl feed (E+7 CY) ==									
Production	1881646.53	462515.60	174585.68	507903.31	179068.60	335995.29	131965.03	4538.05	85074.99
Private consumption	204944.35	45118.51	16621.00	43905.91	22324.52	43350.59	20430.01	767.50	12426.30
Public consumption	92699.83	25414.72	9702.01	15056.10	9377.20	17428.30	8332.10	471.60	6917.80
Investment demand	253165.77	64919.80	20052.15	65061.54	22850.38	42765.96	21133.28	1255.78	15126.87
Intermediate use	1248637.80	301385.25	114023.78	361234.92	117858.74	229666.57	74368.81	2378.68	47721.06
Trade and transport input	59934.71	12021.68	6059.83	11845.48	7167.82	13679.62	5525.52	256.62	3378.13
Net export	29920.73	15537.67	8837.31	12866.08	218.59	-9528.55	2712.30	-573.67	-149.00
Net stock increase	-7656.65	-1882.03	-710.41	-2066.72	-728.65	-1367.21	-536.98	-18.47	-346.18
== Carbohydratefeed (E+3 Gcal) ==									
Production	231050.75	45461.98	17742.77	38188.13	33669.36	31461.80	41194.77	1910.21	21421.73
Intermediate use	239024.89	84402.47	20920.71	18847.37	10621.17	17591.50	74423.04	3398.13	8820.49
Net export	-484.15	-37466.74	-2602.77	20578.70	24139.65	14890.20	-31892.86	-1426.00	13295.67
Net stock increase	-7489.99	-1473.75	-575.17	-1237.95	-1091.46	-1019.90	-1335.41	-61.92	-694.43
== Protein feed (E+3 Gcal) ==									
Production	191610.47	47308.67	17987.89	37340.56	33440.73	15594.68	20772.53	1007.37	18158.03
Intermediate use	212296.32	50677.08	23528.46	40144.15	34522.74	21735.17	28518.71	747.63	12422.38
Net export	-14033.41	-1725.92	-4916.06	-1507.18	79.01	-5599.06	-7024.99	294.72	6366.07
Net stock increase	-6652.44	-1642.49	-624.51	-1296.41	-1161.01	-541.42	-721.19	-34.97	-630.42

Regional market prices (Yuan per kg or mcal)

	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
Milled rice	2.608	2.102	2.013	1.851	2.368	2.280	2.873	2.359
Wheat flour	1.820	1.635	1.736	1.772	1.991	1.841	1.967	1.850
Maize	1.118	1.336	1.382	1.540	1.420	1.362	1.408	1.268
Other staple food	3.276	3.760	3.734	3.642	4.492	3.992	4.091	3.825
Vegetable oil	8.053	7.379	7.801	7.700	10.840	7.701	7.602	7.868
Sugar	3.996	4.385	4.117	3.941	4.002	3.976	4.619	4.078
Fruits	1.287	1.512	1.590	1.531	2.494	1.746	1.728	1.129
Vegetables	0.932	1.095	1.870	1.797	1.952	1.326	1.014	0.903
Ruminant meat	10.849	9.988	12.540	10.270	11.075	9.818	8.589	9.925
Pork	11.472	10.441	12.580	11.042	13.202	10.215	10.567	10.017
Poultry meat	11.295	11.962	13.728	13.394	17.341	16.321	15.138	12.381
Milk	3.183	2.771	3.071	4.323	4.779	4.749	2.896	2.631
Eggs	5.765	6.108	6.569	7.636	8.441	7.854	6.679	6.038
Fish	6.685	7.192	7.542	6.086	8.737	8.900	5.526	6.875
Non-food excl feed	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Carbohydrate feed	0.308	0.278	0.271	0.381	0.396	0.280	0.277	0.287
Protein feed	0.519	0.468	0.531	0.629	0.668	0.423	0.462	0.503

Local commodity balances in 1000 gcal,mt,mwh

	Cropresidu	Grass	Greenfeed	Hh.waste	Anim.fert	Nightsoil	Anim.power	Mach.power
== Beijing ==								
Supply volume	933.72	448.36	127.50	998.52	31.72	5.46	1.80	211.84
Demand volume	569.38	424.28	127.50	992.29	31.72	5.46	1.83	211.84
Unused surplus	364.35	24.08	0.00	6.22	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.03	0.00
== Tianjin ==								
Supply volume	771.81	292.00	25.00	828.27	25.61	5.13	23.82	231.15
Demand volume	635.78	281.68	25.00	711.22	25.61	5.13	23.79	231.15
Unused surplus	136.03	10.32	0.00	117.06	0.00	0.00	0.03	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
== Hebei ==								
Supply volume	15514.35	6601.51	467.50	11081.65	446.24	99.00	439.40	4254.15
Demand volume	10795.72	6338.48	467.50	9697.82	446.24	99.00	439.48	4254.15
Unused surplus	4718.63	263.04	0.00	1383.82	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.08	0.00
== Shanxi ==								
Supply volume	5252.76	6516.36	612.50	4953.75	112.17	36.04	271.60	1363.82
Demand volume	5252.76	6172.65	612.50	3074.70	112.17	36.04	271.24	1363.82
Unused surplus	0.00	343.71	0.00	1879.04	0.00	0.00	0.36	0.00
== Shandong ==								
Supply volume	14441.30	2811.65	90.00	12971.39	848.00	129.02	1221.11	5243.75
Demand volume	14441.30	2656.15	90.00	12971.39	848.00	129.02	1220.85	5243.75
Unused surplus	0.00	155.50	0.00	0.00	0.00	0.00	0.26	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Local commodity balances in 1000 gcal,mt,mwh (continued)

	Cropresidu	Grass	Greenfeed	Hh.waste	Anim.fert	Nightsoil	Anim.power	Mach.power
== Henan ==								
Supply volume	13648.16	7554.26	55.00	15695.27	708.23	128.58	1721.62	4510.81
Demand volume	13648.16	7092.01	55.00	14222.93	708.23	128.58	1721.10	4510.81
Unused surplus	0.00	462.25	0.00	1472.34	0.00	0.00	0.52	0.00
== Liaoning ==								
Supply volume	9123.50	4424.04	105.00	4806.76	221.54	25.86	214.66	647.85
Demand volume	7625.46	4403.11	105.00	4806.76	221.54	25.86	215.22	647.85
Unused surplus	1498.04	20.93	0.00	0.00	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.57	0.00
== Jilin ==								
Supply volume	14541.18	8633.58	57.50	3319.32	193.92	17.52	482.04	637.03
Demand volume	7967.12	8479.80	57.50	3319.32	193.92	17.52	481.49	637.03
Unused surplus	6574.07	153.78	0.00	0.00	0.00	0.00	0.55	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
== Heilongjiang ==								
Supply volume	21576.13	10387.97	1160.00	4379.37	286.88	48.22	424.67	1012.60
Demand volume	8845.76	10057.67	1160.00	4379.37	286.88	48.22	423.99	1012.60
Unused surplus	12730.37	330.30	0.00	0.00	0.00	0.00	0.68	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
== Shanghai ==								
Supply volume	950.62	177.60	97.50	891.34	27.85	3.32	0.95	103.93
Demand volume	397.42	175.39	97.50	891.34	27.85	3.32	0.99	103.93
Unused surplus	553.20	2.21	0.00	0.00	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00
== Jiangsu ==								
Supply volume	12266.82	1202.39	610.00	9973.39	230.61	79.54	114.94	2396.71
Demand volume	5002.80	1124.21	610.00	9973.39	230.61	79.54	114.99	2396.71
Unused surplus	7264.03	78.18	0.00	0.00	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.05	0.00

Local commodity balances in 1000 gcal,mt,mwh (continued)

	Cropresidu	Grass	Greenfeed	Hh.waste	Anim.fert	Nightsoil	Anim.power	Mach.power
== Zhejiang ==								
Supply volume	5486.46	6604.20	250.00	5787.85	109.83	63.80	73.19	1606.58
Demand volume	1942.23	3174.62	250.00	5787.85	109.83	63.80	73.03	1606.58
Unused surplus	3544.23	3429.58	0.00	0.00	0.00	0.00	0.16	0.00
== Anhui ==								
Supply volume	9585.77	3853.01	505.00	9806.13	358.02	97.48	998.00	2399.59
Demand volume	9585.77	3725.70	505.00	9806.13	358.02	97.48	998.90	2399.59
Unused surplus	0.00	127.32	0.00	0.00	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.91	0.00
== Jiangxi ==								
Supply volume	9431.43	7727.37	4139.91	6720.29	227.64	77.19	801.49	724.98
Demand volume	7036.45	7727.37	4139.91	6720.29	227.64	77.19	801.25	724.98
Unused surplus	2394.98	0.00	0.00	0.00	0.00	0.00	0.25	0.00
== Hubei ==								
Supply volume	9715.84	8758.98	1862.50	8346.76	326.19	89.09	853.24	1159.12
Demand volume	9155.58	8758.98	1862.50	8346.76	326.19	89.09	853.30	1159.12
Unused surplus	560.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.06	0.00
== Hunan ==								
Supply volume	14623.29	12622.61	7344.34	10368.24	451.37	126.03	911.49	1527.46
Demand volume	10391.70	12622.61	7344.34	10368.24	451.37	126.03	910.92	1527.46
Unused surplus	4231.59	0.00	0.00	0.00	0.00	0.00	0.57	0.00
== Fujian ==								
Supply volume	4816.74	5060.85	2706.54	4718.68	117.58	36.64	202.33	627.98
Demand volume	2631.79	3702.23	2706.54	3977.25	117.58	36.64	201.99	627.98
Unused surplus	2184.95	1358.62	0.00	741.42	0.00	0.00	0.35	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Local commodity balances in 1000 gcal,mt,mwh (continued)

	Cropresidu	Grass	Greenfeed	Hh.waste	Anim.fert	Nightsoil	Anim.power	Mach.power
== Guangdong ==								
Supply volume	7240.12	6227.01	5428.24	9859.99	345.25	79.64	826.82	1217.08
Demand volume	7240.12	6227.01	5428.24	7941.82	345.25	79.64	826.86	1217.08
Unused surplus	0.00	0.00	0.00	1918.17	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.04	0.00
== Guangxi ==								
Supply volume	9114.67	11970.11	6998.64	7212.69	473.75	78.39	1472.50	1264.24
Demand volume	9114.67	11970.11	6998.64	6343.98	473.75	78.39	1472.04	1264.24
Unused surplus	0.00	0.00	0.00	868.71	0.00	0.00	0.47	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
== Hainan ==								
Supply volume	1131.72	2520.62	527.39	1078.62	74.63	9.12	195.16	129.09
Demand volume	1131.72	2520.62	527.39	890.77	74.63	9.12	195.10	129.09
Unused surplus	0.00	0.00	0.00	187.84	0.00	0.00	0.06	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
== Chongqing ==								
Supply volume	5804.65	487.25	1915.00	4751.31	223.19	54.21	73.63	426.60
Demand volume	3890.56	487.25	1915.00	4403.72	223.19	54.21	73.33	426.60
Unused surplus	1914.09	0.00	0.00	347.58	0.00	0.00	0.30	0.00
== Sichuan ==								
Supply volume	17619.68	28638.27	7687.50	13714.55	811.93	161.90	1071.20	1072.41
Demand volume	17619.68	28638.27	7687.50	13714.55	811.93	161.90	1070.42	1072.41
Unused surplus	0.00	0.00	0.00	0.00	0.00	0.00	0.79	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
== Guizhou ==								
Supply volume	5759.91	8119.10	1623.75	6200.66	416.69	57.24	1228.46	487.82
Demand volume	5759.91	8119.10	1623.75	4059.41	416.69	57.24	1228.39	487.82
Unused surplus	0.00	0.00	0.00	2141.24	0.00	0.00	0.07	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Local commodity balances in 1000 gcal,mt,mwh (continued)

	Cropresidu	Grass	Greenfeed	Hh.waste	Anim.fert	Nightsoil	Anim.power	Mach.power
== Yunnan ==								
Supply volume	6694.12	15955.37	3803.77	7443.52	468.43	64.65	1252.84	983.97
Demand volume	6694.12	15779.45	3803.77	5029.51	468.43	64.65	1253.73	983.97
Unused surplus	0.00	175.92	0.00	2414.02	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.88	0.00
== Tibet ==								
Supply volume	177.29	39109.57	87.50	485.41	5.12	4.93	93.72	50.70
Demand volume	177.29	36780.46	87.50	159.66	5.12	4.93	93.66	50.70
Unused surplus	0.00	2329.11	0.00	325.76	0.00	0.00	0.06	0.00
== Qinghai ==								
Supply volume	284.08	26596.95	472.50	770.99	17.66	7.09	32.47	158.36
Demand volume	284.08	26596.95	472.50	462.95	17.66	7.09	32.30	158.36
Unused surplus	0.00	0.00	0.00	308.04	0.00	0.00	0.17	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
== Inner Mongolia ==								
Supply volume	6938.35	56491.00	2455.00	3205.62	113.02	33.91	223.17	945.23
Demand volume	6938.35	46900.28	2455.00	3205.62	113.02	33.91	222.98	945.23
Unused surplus	0.00	9590.72	0.00	0.00	0.00	0.00	0.19	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
== Shaanxi ==								
Supply volume	4931.66	10825.17	492.50	5540.32	118.47	27.12	364.32	840.87
Demand volume	4931.66	10365.84	492.50	3710.93	118.47	27.12	364.76	840.87
Unused surplus	0.00	459.33	0.00	1829.39	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.44	0.00

Local commodity balances in 1000 gcal,mt,mwh (continued)

	Cropresidu	Grass	Greenfeed	Hh.waste	Anim.fert	Nightsoil	Anim.power	Mach.power
== Gansu ==								
Supply volume	3788.22	19030.93	4115.00	4354.01	172.61	39.09	397.36	867.35
Demand volume	3788.22	18870.18	4115.00	2960.00	172.61	39.09	397.99	867.35
Unused surplus	0.00	160.75	0.00	1394.00	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.63	0.00
== Ningxia ==								
Supply volume	872.52	2457.12	560.00	878.50	30.78	6.76	55.92	308.11
Demand volume	872.52	2326.67	560.00	878.50	30.78	6.76	56.13	308.11
Unused surplus	0.00	130.45	0.00	0.00	0.00	0.00	0.00	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-0.21	0.00
== Xinjiang ==								
Supply volume	3227.07	32931.48	3305.00	2881.72	143.47	31.83	174.36	568.60
Demand volume	3045.06	30939.81	3305.00	786.52	143.47	31.83	173.90	568.60
Unused surplus	182.01	1991.67	0.00	2095.21	0.00	0.00	0.47	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
== Whole of China ==								
Supply volume	236263.99	355036.69	59687.59	184024.89	8138.41	1723.81	16218.28	37979.78
Demand volume	187413.15	333438.92	59687.59	164595.02	8138.41	1723.81	16215.94	37979.78
Unused surplus	48850.84	21597.78	0.00	19429.87	0.00	0.00	6.29	0.00
Net stock increase	0.00	0.00	0.00	0.00	0.00	0.00	-3.96	0.00

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:: Local commodity prices in Yuan per mcal,kg,kwh ::
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	Cropresidu	Grass	Greenfeed	Hh.waste	Anim.fert	Nightsoil	Anim.power	Mach.power
Beijing	0.081	0.081	0.244	0.102	2.800	2.800	4.024	4.024
Tianjin	0.092	0.092	0.275	0.115	2.704	2.704	4.946	4.946
Hebei	0.089	0.089	0.268	0.112	2.197	2.197	2.312	2.312
Shanxi	0.070	0.070	0.211	0.088	2.452	2.452	1.372	1.372
Shandong	0.088	0.088	0.264	0.110	2.429	2.429	1.586	1.586
Henan	0.076	0.076	0.228	0.095	2.204	2.204	3.748	3.748
Liaoning	0.072	0.072	0.217	0.090	2.261	2.261	1.559	1.559
Jilin	0.078	0.078	0.234	0.097	2.798	2.798	1.767	1.767
Heilongjiang	0.075	0.075	0.225	0.094	3.130	3.130	1.682	1.682
Shanghai	0.093	0.093	0.278	0.116	2.206	2.206	3.972	3.372
Jiangsu	0.102	0.102	0.306	0.128	2.410	2.410	2.616	2.616
Zhejiang	0.105	0.105	0.315	0.131	2.573	2.573	3.972	3.372
Anhui	0.055	0.055	0.165	0.069	2.168	2.168	4.128	4.128
Jiangxi	0.108	0.108	0.324	0.135	2.623	2.623	3.701	3.701
Hubei	0.095	0.095	0.285	0.119	2.249	2.249	4.487	4.487
Hunan	0.102	0.102	0.307	0.128	1.484	1.484	5.061	5.061
Fujian	0.106	0.106	0.317	0.132	2.100	2.100	4.233	4.233
Guangdong	0.111	0.111	0.334	0.139	2.353	2.353	2.968	2.968
Guangxi	0.101	0.101	0.304	0.127	2.310	2.310	3.822	3.822
Hainan	0.113	0.113	0.339	0.141	2.300	2.300	2.968	2.968
Chongqing	0.084	0.084	0.252	0.105	2.489	2.489	3.663	3.663
Sichuan	0.048	0.048	0.145	0.060	2.629	2.629	4.587	4.587
Guizhou	0.101	0.101	0.304	0.127	2.988	2.988	2.593	2.593
Yunnan	0.081	0.081	0.242	0.101	2.766	2.766	2.331	2.331
Tibet	0.074	0.074	0.222	0.092	2.470	2.470	1.093	1.093
Qinghai	0.074	0.074	0.222	0.092	2.470	2.470	1.093	1.093
Inner Mongolia	0.079	0.079	0.237	0.099	2.519	2.519	1.186	1.186
Shaanxi	0.071	0.071	0.212	0.088	2.328	2.328	1.162	1.162
Gansu	0.084	0.084	0.251	0.105	2.538	2.538	1.184	1.184
Ningxia	0.066	0.066	0.198	0.082	2.204	2.204	1.572	1.572
Xinjiang	0.090	0.090	0.269	0.112	2.709	2.709	1.228	1.228

Regional feed balances

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Maize (E+3 Gcal) ==									
Supply volume own region	297107.62	98475.30	88131.36	14003.62	7003.23	6541.86	40339.07	72.61	42540.58
Demand volume	282150.82	75198.72	25575.52	21686.64	22931.10	31230.48	92882.82	1937.12	10708.41
Net export	20040.56	21096.89	60072.94	-6951.81	-14103.62	-21904.99	-46973.05	-1559.25	30363.46
Net stock increase	-5083.77	2179.68	2482.91	-731.21	-1824.25	-2783.64	-5570.71	-305.26	1468.71
== Carbohydrate feed (E+3 Gcal) ==									
Supply volume own region	231050.75	45461.98	17742.77	38188.13	33669.36	31461.80	41194.77	1910.21	21421.73
Demand volume	239024.89	84402.47	20920.71	18847.37	10621.17	17591.50	74423.04	3398.13	8820.49
Net export	-484.15	-37466.74	-2602.77	20578.70	24139.65	14890.20	-31892.86	-1426.00	13295.67
Net stock increase	-7489.99	-1473.75	-575.17	-1237.95	-1091.46	-1019.90	-1335.41	-61.92	-694.43
== Protein feed (E+3 Gcal) ==									
Supply volume own region	191610.47	47308.67	17987.89	37340.56	33440.73	15594.68	20772.53	1007.37	18158.03
Demand volume	212296.32	50677.08	23528.46	40144.15	34522.74	21735.17	28518.71	747.63	12422.38
Net export	-14033.41	-1725.92	-4916.06	-1507.18	79.01	-5599.06	-7024.99	294.72	6366.07
Net stock increase	-6652.44	-1642.49	-624.51	-1296.41	-1161.01	-541.42	-721.19	-34.97	-630.42
== Crop residuals (E+3 Gcal) ==									
Supply volume own region	236263.99	50562.11	45240.81	28289.68	33770.57	22303.24	35878.36	461.38	19757.84
Demand volume	187413.15	45343.09	24438.33	16928.22	26583.74	20118.29	33964.27	461.38	19575.83
Unused surplus	48850.84	5219.01	20802.48	11361.46	7186.83	2184.95	1914.09	0.00	182.01
== Utilizible grass (E+3 Gcal) ==									
Supply volume own region	355036.69	24224.14	23445.58	11837.21	29108.95	25778.59	53199.99	65706.52	121735.70
Demand volume	333438.92	22965.25	22940.58	8199.92	29108.95	24419.97	53024.07	63377.41	109402.78
Unused surplus	21597.78	1258.89	505.01	3637.30	0.00	1358.62	175.92	2329.11	12332.93

Regional feed balances (continued)

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Greenfeed (E+3 Gcal) ==									
Supply volume own region	59687.59	1377.50	1322.50	1462.50	13346.75	15660.80	15030.03	560.00	10927.50
Demand volume	59687.59	1377.50	1322.50	1462.50	13346.75	15660.80	15030.03	560.00	10927.50
Unused surplus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
== Household waste (E+3 Gcal) ==									
Supply volume own region	184024.89	46528.85	12505.44	26458.71	25435.29	22869.97	32110.04	1256.40	16860.18
Demand volume	164595.02	41670.37	12505.44	26458.71	25435.29	19153.83	27207.19	622.61	11541.57
Unused surplus	19429.87	4858.48	0.00	0.00	0.00	3716.14	4902.84	633.79	5318.61
== Total feed (E+3 Gcal) ==									
Supply volume own region	1554781.99	313938.55	206376.36	157580.41	175774.89	140210.96	238524.78	70974.50	251401.55
Demand volume	1478606.70	321634.48	131231.54	133727.52	162549.75	149910.05	325050.13	71104.28	183398.95
Net export	5523.01	-18095.77	52554.11	12119.71	10115.04	-12613.85	-85890.89	-2690.53	50025.19
Net stock increase	-19226.20	-936.55	1283.22	-3265.57	-4076.73	-4344.96	-7627.31	-402.15	143.86
Unused surplus	89878.48	11336.39	21307.49	14998.76	7186.83	7259.72	6992.86	2962.90	17833.54

Land balances

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Million hectare ==									
Irrigated crop land	59.995	17.232	3.945	9.882	8.043	5.413	6.387	0.391	8.703
Rainfed crop land	68.694	12.137	16.681	3.827	3.866	4.623	12.095	0.644	14.820
Tree crop land	9.222	2.008	0.678	1.324	1.047	2.292	1.241	0.008	0.624
Natural grass land	330.979	14.481	13.700	3.906	14.585	11.978	35.306	102.377	134.645
Sown grass land	5.673	0.646	0.480	0.090	0.151	0.096	0.142	0.194	3.874
Forests and bushes	171.710	5.301	29.570	6.065	17.641	22.545	38.466	12.274	39.847
Built-up land incl. roads	27.209	6.919	3.859	3.605	2.841	2.340	3.257	0.323	4.066
Inland water bodies	39.808	4.520	4.563	6.200	5.078	2.789	2.179	7.250	7.230
Unused land	225.517	6.306	5.620	1.059	3.265	5.412	13.461	57.512	132.881
Total land surface	938.807	69.550	79.096	35.958	56.518	57.487	112.534	180.973	346.691
== Hectare per inhabitant ==									
Irrigated crop land	0.048	0.057	0.038	0.051	0.049	0.032	0.033	0.051	0.080
Rainfed crop land	0.055	0.040	0.163	0.020	0.024	0.027	0.062	0.084	0.136
Tree crop land	0.007	0.007	0.007	0.007	0.006	0.013	0.006	0.001	0.006
Natural grass land	0.266	0.048	0.134	0.020	0.089	0.070	0.181	13.306	1.235
Sown grass land	0.005	0.002	0.005	0.000	0.001	0.001	0.001	0.025	0.036
Forests and bushes	0.138	0.017	0.289	0.032	0.108	0.133	0.197	1.595	0.365
Built-up land incl. roads	0.022	0.023	0.038	0.019	0.017	0.014	0.017	0.042	0.037
Inland water bodies	0.032	0.015	0.045	0.032	0.031	0.016	0.011	0.942	0.066
Unused land	0.181	0.021	0.055	0.006	0.020	0.032	0.069	7.475	1.219
Total land surface	0.754	0.229	0.772	0.187	0.345	0.338	0.577	23.521	3.179

Herd sizes

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Million animal places ==									
Buffaloes	20.866	0.487	0.000	1.752	4.689	6.734	7.185	0.000	0.019
Draught cattle	39.007	12.966	3.366	2.695	4.903	3.964	7.174	0.279	3.660
Other draught animals	17.670	3.492	3.208	0.164	0.067	0.326	2.872	0.954	6.586
Milk cattle	2.874	0.483	0.764	0.126	0.048	0.054	0.168	0.245	0.987
Meat cattle	38.776	12.562	5.316	2.899	2.192	1.966	5.563	1.600	6.677
Sheep and goat	234.006	58.662	10.208	13.853	4.588	3.096	21.084	31.706	90.810
Yaks	12.251	0.002	0.000	0.000	0.000	0.000	3.930	7.247	1.073
Hogs	348.269	56.746	22.548	36.657	60.098	42.666	107.292	1.158	21.104
Poultry	2542.882	837.123	392.075	429.732	166.723	323.001	301.222	1.312	91.693
== Places per 1000 inhabitants ==									
Buffaloes	16.765	1.599	0.000	9.125	28.602	39.587	36.855	0.000	0.175
Draught cattle	31.341	42.605	32.843	14.034	29.904	23.303	36.800	36.208	33.565
Other draught animals	14.198	11.475	31.298	0.855	0.412	1.918	14.734	124.011	60.394
Milk cattle	2.309	1.586	7.454	0.654	0.293	0.318	0.862	31.843	9.053
Meat cattle	31.155	41.276	51.867	15.098	13.371	11.561	28.537	207.924	61.230
Sheep and goat	188.017	192.759	99.591	72.137	27.987	18.198	108.152	4120.841	832.746
Yaks	9.844	0.007	0.000	0.000	0.000	0.000	20.158	941.899	9.836
Hogs	279.825	186.464	219.992	190.888	366.558	250.829	550.373	150.494	193.527
Poultry	2043.136	2750.736	3825.345	2237.765	1016.910	1898.877	1545.164	170.521	840.844

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::   Agricultural labour in millions   ::
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	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
Crop employment, FTE	214.348	52.470	10.474	33.015	29.036	27.527	41.905	1.035	18.886
Livestock employment, FTE	38.651	9.256	2.435	3.763	5.125	4.286	9.859	0.420	3.506
Fisheries employment, FTE	9.611	1.282	0.494	2.065	1.977	2.332	1.392	0.001	0.068
Forestry employment, FTE	10.480	1.756	0.311	1.571	2.137	2.398	1.829	0.023	0.455
Off-farm and idle, FTE	57.862	13.724	4.974	6.897	7.278	4.680	14.074	0.847	5.388
Agricultural labour force	330.952	78.488	18.688	47.311	45.554	41.223	69.059	2.326	28.303

Supply activity levels

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Crops ==									
Paddy (E+3 Mt)	200736.26	6281.00	16228.00	46253.00	59503.00	37594.00	32032.00	5.26	2840.00
Wheat (E+3 Mt)	123289.09	64668.00	3979.00	21123.00	4866.00	276.09	10124.00	1066.00	17187.00
Maize (E+3 Mt)	104321.50	34577.00	30945.00	4917.00	2459.00	2297.00	14164.00	25.49	14937.00
Minor grain crops (E+3 Mt)	15052.00	2951.00	2639.00	2390.00	375.00	216.00	2099.00	677.00	3705.00
Roots and tubers (E+3 Mt)	31927.30	6847.00	1476.00	3927.00	3344.00	4886.00	8638.00	143.30	2666.00
Soybean (E+3 Mt)	14007.35	3205.15	5081.16	1790.67	1054.53	739.15	772.66	1.55	1362.49
Groundnuts (E+3 Mt)	10612.83	6243.60	205.70	1054.90	970.20	1614.80	465.30	0.03	58.30
Oilseeds (E+3 Mt)	13125.16	1124.16	346.50	3416.60	3764.20	187.00	2107.60	239.80	1939.30
Sugarcane (E+3 Mt)	78885.04	172.72	0.00	1054.71	4960.25	56340.57	16356.79	0.00	0.00
Sugarbeets (E+3 Mt)	14968.27	754.21	5206.81	39.72	0.00	0.00	4.59	0.19	8962.75
Fruits (E+3 Mt)	56842.39	20177.41	3487.99	5570.29	4400.33	13024.11	3707.11	22.00	6453.15
Vegetables (E+3 Mt)	291875.31	85583.84	27419.58	44044.80	41433.08	36249.65	38376.70	568.79	18198.87
Cotton (E+3 Mt)	4604.09	1443.00	15.00	860.00	969.00	1.09	110.00	0.00	1206.00
Other nonfood crops(E+3 Mt)	3501.80	570.50	309.40	173.80	445.20	226.80	1563.80	0.19	212.10
== Livestock (meat output) ==									
Buffaloes (E+3 Mt)	156.49	3.65	0.00	13.14	35.17	50.50	53.89	0.00	0.14
Draught cattle (E+3 Mt)	281.61	100.43	26.83	18.67	42.78	24.97	40.40	1.80	25.74
Other draught anim (E+3 Mt)	158.66	30.64	28.53	1.48	0.61	2.92	25.37	8.55	60.57
Milk cattle (E+3 Mt)	67.72	12.13	18.41	2.14	1.20	1.17	2.91	4.91	24.84
Meat cattle (E+3 Mt)	2721.68	1128.50	429.81	250.50	183.27	89.36	174.75	64.54	400.95
Sheep and goat (E+3 Mt)	1129.87	280.65	33.89	85.31	26.82	16.04	90.69	87.01	509.46
Yaks (E+3 Mt)	91.74	0.02	0.00	0.00	0.00	0.00	29.43	54.27	8.03
Hogs (E+3 Mt)	28692.46	5073.42	2004.60	3758.10	5409.08	4079.81	6798.68	62.60	1506.17
Poultry (E+3 Mt)	6491.74	1751.25	978.13	1169.97	414.10	1212.84	812.95	1.27	151.23

Supply activity levels (continued)

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Other farm ==									
Machine power (E+3 Mwh)	37979.78	15815.51	2297.48	6506.80	3411.56	3238.39	2970.80	209.06	3530.17
Hh waste for feed(E+3 Gcal)	184024.89	46528.85	12505.44	26458.71	25435.29	22869.97	32110.04	1256.40	16860.18
Household manure (E+3 Mt)	1723.81	403.23	91.61	244.14	292.32	203.79	338.00	12.02	138.70
Greenfeed (E+3 Gcal)	59687.59	1377.50	1322.50	1462.50	13346.75	15660.80	15030.03	560.00	10927.50
Utilizible grass (E+3 Gcal)	355036.69	24224.14	23445.58	11837.21	29108.95	25778.59	53199.99	65706.52	121735.70
== Non-farm ==									
Fish (E+3 Mt)	23318.06	5064.85	2148.97	6470.48	2783.37	5971.10	691.30	3.50	184.50
Forest products (E+7 CY)	8038.24	1373.68	396.98	1322.13	1307.29	2062.48	1074.59	18.09	483.00
Industry,construct (E+7 CY)	1340094.09	324885.41	124872.30	382995.57	125558.68	238549.86	87677.45	2512.61	53042.22
Services (E+7 CY)	524471.29	133985.24	49069.44	122415.27	50646.90	94927.47	41470.32	1954.12	30002.52

Unit values of supply activities

	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Total value in Yuan/kg crop ==								
Paddy	1.440	1.307	1.381	1.220	1.405	1.385	1.702	1.502
Wheat	1.259	1.005	1.171	1.206	1.482	1.288	1.299	1.309
Maize	1.053	0.902	1.178	1.187	1.215	1.235	1.175	0.997
Minor grain crops	1.199	0.872	1.227	1.062	1.214	1.247	0.842	0.966
Roots and tubers	1.738	1.426	1.751	1.398	1.785	2.318	1.651	1.625
Soybean	2.325	2.320	2.320	2.096	2.667	2.512	2.050	2.186
Groundnuts	2.806	2.670	2.852	2.035	2.930	3.240	2.419	2.584
Oilseeds	2.629	3.217	2.927	2.656	3.305	2.486	2.642	2.790
Sugarcane	0.248	0.000	0.286	0.252	0.256	0.191	0.000	0.000
Sugarbeets	0.338	0.314	0.361	0.000	0.000	0.262	0.339	0.292
Fruits	0.945	0.626	0.929	0.619	1.146	0.964	1.371	0.898
Vegetables	0.518	0.518	1.240	1.066	1.189	0.732	0.567	0.589
Cotton	14.005	14.683	13.716	12.779	10.995	13.262	0.000	13.152
Other nonfood crops	1.966	2.850	1.854	3.880	2.850	6.918	1.425	1.425
== Total value in Yuan/kg meat ==								
Buffaloes	238.415	0.000	229.280	291.470	229.294	202.731	0.000	96.293
Draught cattle	138.715	96.557	218.009	177.540	201.956	206.759	65.286	76.196
Other draught animals	32.051	35.201	33.622	77.719	75.291	62.887	23.807	23.948
Milk cattle	253.548	169.451	475.377	221.834	338.606	321.567	143.195	125.349
Meat cattle	10.859	8.515	9.682	10.365	10.910	13.188	9.151	9.326
Sheep and goat	18.284	16.951	17.315	17.648	19.614	21.303	15.452	14.329
Yaks	18.220	0.000	0.000	0.000	0.000	20.615	15.274	15.434
Hogs	10.672	10.087	10.735	10.538	11.731	9.301	10.184	9.238
Poultry	25.434	19.113	21.547	24.158	19.130	23.762	71.568	38.870

Unit values of supply activities (continued)

	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Yuan per kwh, mcal or kg ==								
Machine power	2.461	1.671	3.372	4.577	3.547	3.380	1.093	1.220
Household waste	0.103	0.093	0.106	0.127	0.134	0.089	0.092	0.098
Household manure	2.311	2.821	2.353	2.018	2.289	2.693	2.470	2.515
Greenfeed	0.239	0.225	0.257	0.309	0.318	0.200	0.222	0.249
Utilizible grass	0.080	0.076	0.088	0.102	0.106	0.066	0.074	0.082
== Yuan per kg or 10 CY ==								
Fish	5.711	6.138	6.798	6.086	7.538	8.900	5.526	6.875
Forest products	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Industry and construction	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Services	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Cropping types in volumes

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Irrigated cropping ==									
Cultivated area in E+6 ha	59.995	17.232	3.945	9.882	8.043	5.413	6.387	0.391	8.703
Grain output in E+6 Mt	347.198	91.295	19.785	67.511	63.375	37.629	39.139	0.774	27.691
Non-grain output in E+6 Mt	236.680	90.764	11.547	39.224	29.354	27.195	15.550	0.475	22.571
Labour input in E+6 pers	120.332	35.151	2.715	24.219	19.612	14.172	15.659	0.455	8.349
Animal power input (E+6 Mwh)	8.614	2.444	0.243	0.813	1.815	1.497	1.246	0.072	0.483
Machinery input (E+6 Mwh)	27.777	12.597	0.713	5.457	2.800	2.372	1.572	0.078	2.189
Chemical fertilizer (E+6 Mt)	29.306	10.068	1.364	5.801	4.097	3.059	2.609	0.039	2.269
Organic fertilizer (E+6 Mt)	6.699	2.141	0.288	0.796	1.049	0.828	1.130	0.015	0.453
== Rainfed cropping ==									
Cultivated area in E+6 ha	68.694	12.137	16.681	3.827	3.866	4.623	12.095	0.644	14.820
Grain output in E+6 Mt	96.201	17.182	34.006	7.172	3.828	2.754	19.280	1.000	10.978
Non-grain output in E+6 Mt	241.037	20.224	29.385	18.531	28.687	76.306	53.772	0.484	13.648
Labour input in E+6 pers	85.489	14.292	7.236	7.961	8.764	11.401	25.690	0.576	9.569
Animal power input (E+6 Mwh)	7.602	1.234	0.877	0.375	0.750	1.199	2.380	0.054	0.733
Machinery input (E+6 Mwh)	10.202	3.219	1.584	1.050	0.612	0.867	1.399	0.131	1.341
Chemical fertilizer (E+6 Mt)	11.577	2.110	2.663	1.083	1.062	1.396	2.205	0.051	1.007
Organic fertilizer (E+6 Mt)	3.163	0.434	0.506	0.175	0.249	0.387	1.129	0.019	0.265
== Tree cropping ==									
Cultivated area in E+6 ha	9.222	2.008	0.678	1.324	1.047	2.292	1.241	0.008	0.624
Non-grain output in E+6 Mt	42.632	15.133	2.616	4.178	3.300	9.768	2.780	0.017	4.840
Labour input in E+6 pers	8.526	3.027	0.523	0.836	0.660	1.954	0.556	0.003	0.968

Types of livestock raising in volumes

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Draught animal system ==									
Million buffaloes	20.866	0.487	0.000	1.752	4.689	6.734	7.185	0.000	0.019
Million draught cattle	39.007	12.966	3.366	2.695	4.903	3.964	7.174	0.279	3.660
Million draught animals nes	17.670	3.492	3.208	0.164	0.067	0.326	2.872	0.954	6.586
Slaughtered buffaloes (E+6)	2.087	0.049	0.000	0.175	0.469	0.673	0.718	0.000	0.002
Slaughtered cattle (E+6)	3.755	1.339	0.358	0.249	0.570	0.333	0.539	0.024	0.343
Slaughtered other (E+6)	1.788	0.349	0.321	0.016	0.007	0.033	0.287	0.096	0.678
Meat output in E+3 Mt	596.768	134.715	55.353	33.288	78.559	78.395	119.655	10.355	86.448
Milk output in E+3 Mt	1877.918	43.796	0.000	157.702	422.044	606.035	646.621	0.000	1.721
Animalpower output (E+6 Mwh)	16.218	3.679	1.121	1.187	2.566	2.697	3.626	0.126	1.215
Manure output in E+3 Mt	2472.520	548.828	168.063	150.488	349.704	430.657	667.304	3.560	153.917
Labour input in E+6 pers	5.140	1.031	0.169	0.470	0.942	0.811	1.415	0.020	0.282
Energy marketfeed (E+6 Gcal)	140.701	46.971	10.151	12.157	8.223	17.225	40.210	0.749	5.016
Energy local feed (E+6 Gcal)	231.331	30.463	21.142	10.462	38.950	38.685	43.827	4.963	42.838
== Grazing system ==									
Million milk cattle	1.119	0.066	0.221	0.013	0.021	0.010	0.022	0.174	0.592
Million meat cattle	10.004	0.792	1.145	0.137	0.845	0.666	0.913	1.399	4.107
Million sheep and goat	94.170	4.788	2.207	1.075	1.780	1.088	2.934	23.549	56.749
Million yaks	12.251	0.002	0.000	0.000	0.000	0.000	3.930	7.247	1.073
Slaughtered milkcattle (E+6)	0.247	0.015	0.048	0.002	0.005	0.002	0.003	0.031	0.141
Slaughtered meatcattle (E+6)	4.217	0.395	0.519	0.062	0.526	0.287	0.284	0.487	1.656
Slaughtered sheep/goat (E+6)	30.964	2.132	0.545	0.503	0.853	0.446	0.693	4.756	21.036
Slaughtered yaks (E+6)	1.593	0.000	0.000	0.000	0.000	0.000	0.511	0.942	0.139
Meat output in E+3 Mt	1008.011	80.862	84.393	13.382	70.349	32.501	63.201	158.574	504.749
Milk output in E+3 Mt	2487.756	161.612	341.974	30.960	39.884	25.112	128.409	527.298	1232.507
Labour input in E+6 pers	1.368	0.113	0.072	0.020	0.066	0.034	0.105	0.258	0.701
Energy marketfeed (E+6 Gcal)	7.232	1.056	0.639	0.146	0.137	0.260	2.395	1.890	0.709
Energy local feed (E+6 Gcal)	159.383	5.174	6.535	1.056	4.001	2.790	24.655	55.987	59.184

Types of livestock raising in volumes (continued)

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Trad.mixed ruminant farm ==									
Million milk cattle	1.044	0.221	0.296	0.026	0.018	0.016	0.127	0.065	0.275
Million meat cattle	28.772	11.770	4.171	2.762	1.347	1.301	4.650	0.201	2.570
Million sheep and goat	139.836	53.873	8.001	12.777	2.809	2.007	18.150	8.157	34.061
Slaughtered milkcattle (E+6)	0.210	0.050	0.063	0.004	0.004	0.003	0.020	0.012	0.054
Slaughtered meatcattle (E+6)	16.373	7.113	2.523	1.811	1.074	0.651	1.715	0.140	1.346
Slaughtered sheep/goat (E+6)	73.051	28.698	2.674	8.831	1.521	1.008	6.662	3.374	20.285
Meat output in E+3 Mt	2986.702	1335.610	391.798	323.126	140.695	73.513	234.245	52.042	435.672
Milk output in E+3 Mt	3315.106	992.222	697.122	176.448	56.861	55.019	352.507	172.013	812.914
Manure output in E+3 Mt	1712.093	687.479	194.145	143.033	70.764	58.480	276.232	16.514	265.447
Labour input in E+6 pers	4.361	2.089	0.335	0.463	0.145	0.082	0.416	0.084	0.746
Energy marketfeed (E+6 Gcal)	92.449	49.470	8.796	9.863	1.405	1.970	12.627	2.382	5.937
Energy local feed (E+6 Gcal)	105.090	28.577	14.605	8.355	5.097	3.899	14.983	3.325	26.250
== Specialized dairy farm ==									
Million milk cattle	0.711	0.195	0.247	0.086	0.010	0.028	0.019	0.005	0.120
Slaughtered milkcattle (E+6)	0.145	0.043	0.053	0.013	0.002	0.005	0.003	0.001	0.025
Meat output in E+3 Mt	16.293	4.829	5.922	1.444	0.242	0.554	0.331	0.110	2.860
Milk output in E+3 Mt	2346.252	736.284	750.568	366.227	25.189	80.190	43.967	12.221	331.604
Manure output in E+3 Mt	27.779	7.651	11.085	2.395	0.437	1.142	0.815	0.069	4.185
Labour input in E+6 pers	0.146	0.041	0.056	0.017	0.002	0.005	0.005	0.001	0.019
Energy marketfeed (E+6 Gcal)	2.318	0.757	0.849	0.289	0.025	0.072	0.069	0.018	0.239
Energy local feed (E+6 Gcal)	1.445	0.283	0.465	0.167	0.024	0.071	0.027	0.009	0.399
== Trad.mixed nonruminant farm ==									
Million pigs	298.499	47.776	16.955	28.707	51.717	35.065	98.501	1.098	18.680
Million poultry	1807.569	619.093	289.586	298.983	120.340	191.797	216.986	0.764	70.020
Slaughtered pigs (E+6)	299.117	49.713	16.649	36.814	60.116	41.345	77.474	0.933	16.075
Slaughtered poultry (E+6)	3266.579	986.106	536.761	512.885	215.087	513.662	408.909	1.014	92.157
Meat output in E+3 Mt	26651.824	5088.870	1996.144	3320.404	4648.197	3665.972	6483.407	58.878	1389.951
Egg output in E+3 Mt	7285.854	3365.839	958.104	1221.411	430.818	116.111	608.602	6.027	578.943
Manure output in E+3 Mt	3133.224	725.424	241.839	318.867	483.428	382.140	849.250	2.412	129.864
Labour input in E+6 pers	25.187	5.332	1.548	2.381	3.654	3.020	7.539	0.054	1.658
Energy marketfeed (E+6 Gcal)	362.815	78.174	32.278	35.868	44.245	33.919	121.882	0.898	15.551
Energy local feed (E+6 Gcal)	235.122	45.747	17.448	31.750	43.653	30.432	44.345	0.731	21.015

Types of livestock raising in volumes (continued)

== Intensified nonruminant farm ==

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
Million pigs	49.770	8.970	5.593	7.950	8.380	7.601	8.792	0.060	2.424
Million poultry	735.313	218.030	102.489	130.749	46.383	131.204	84.236	0.548	21.673
Slaughtered pigs (E+6)	74.362	13.665	7.322	13.616	13.682	13.277	9.972	0.079	2.748
Slaughtered poultry (E+6)	1818.341	405.981	249.766	359.208	110.443	431.994	231.809	0.087	29.053
Meat output in E+3 Mt	8532.368	1735.808	986.592	1607.658	1174.979	1626.674	1128.220	4.993	267.446
Egg output in E+3 Mt	5459.771	2104.079	743.269	883.429	364.974	582.848	524.479	7.234	249.459
Manure output in E+3 Mt	792.791	202.585	87.210	111.525	100.869	138.793	126.647	0.220	24.942
Labour input in E+6 pers	2.449	0.649	0.255	0.413	0.317	0.334	0.379	0.002	0.099
Energy marketfeed (E+6 Gcal)	127.956	33.850	17.312	22.355	14.040	17.112	18.641	0.146	4.500
Energy local feed (E+6 Gcal)	12.765	1.112	1.011	1.261	2.750	3.475	1.389	0.006	1.761

Cropping types in billion Yuan

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Irrigated cropping ==									
Output value	700.714	190.620	30.482	150.811	117.823	76.864	69.392	1.502	63.221
Animal manure input value	12.989	4.197	0.700	1.365	1.612	1.571	2.597	0.024	0.923
Animal power input value	28.111	6.579	0.413	3.229	8.069	5.283	3.878	0.079	0.581
Non-agricultural input value	183.492	59.138	9.328	35.112	23.438	21.661	15.269	0.204	19.343
Gross value added	476.123	120.707	20.041	111.105	84.704	48.349	47.647	1.195	42.375
Labour remuneration	308.087	78.239	6.126	69.352	52.571	46.693	36.847	0.930	17.329
Gross operating surplus	168.036	42.468	13.915	41.752	32.134	1.656	10.800	0.265	25.046
== Rainfed cropping ==									
Output value	352.063	49.919	56.411	37.732	42.284	57.146	81.066	1.694	25.811
Animal manure input value	6.731	0.838	1.242	0.311	0.389	0.754	2.634	0.032	0.532
Animal power input value	22.214	3.323	1.487	1.489	3.336	4.232	7.408	0.059	0.881
Non-agricultural input value	75.784	16.250	13.686	9.113	7.596	9.389	11.449	0.227	8.074
Gross value added	247.334	29.508	39.997	26.819	30.963	42.771	59.575	1.376	16.325
Labour remuneration	205.239	30.383	16.366	20.714	23.268	37.316	57.895	1.160	18.137
Gross operating surplus	42.096	-0.875	23.631	6.105	7.695	5.455	1.680	0.217	-1.812
== Tree cropping ==									
Output value	40.092	14.303	1.636	3.876	2.041	11.189	2.679	0.023	4.345
Non-agricultural input value	4.839	1.063	0.442	0.763	0.420	1.399	0.306	0.001	0.446
Gross value added	35.252	13.240	1.194	3.114	1.622	9.789	2.373	0.022	3.899
Labour remuneration	22.412	6.953	1.178	2.687	1.761	6.510	1.318	0.007	1.998
Gross operating surplus	12.841	6.286	0.016	0.427	-0.140	3.280	1.055	0.015	1.901

Types of livestock raising in billion Yuan

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Draught animal system ==									
Value of meat, milk and eggs	10.481	1.309	0.371	0.561	1.863	2.579	3.001	0.084	0.712
Draught power value	50.334	9.904	1.901	4.715	11.408	9.518	11.289	0.138	1.460
Manure output value	6.034	1.260	0.469	0.334	0.720	0.994	1.861	0.009	0.386
Output value n.e.s.	19.008	3.307	0.852	1.526	3.899	3.748	4.719	0.090	0.868
Feed input value	62.029	18.779	4.413	5.458	6.272	9.908	14.459	0.254	2.486
Non-agricultural input value	1.919	0.320	0.064	0.156	0.392	0.369	0.534	0.007	0.077
Gross value added	21.909	-3.319	-0.883	1.523	11.226	6.563	5.878	0.060	0.863
Labour remuneration	12.234	2.203	0.383	0.999	2.505	2.355	3.198	0.044	0.547
Gross operating surplus	9.675	-5.522	-1.266	0.524	8.721	4.208	2.680	0.016	0.316
== Grazing system ==									
Value of meat, milk and eggs	12.939	1.068	1.151	0.199	0.744	0.368	1.001	2.281	6.128
Output value n.e.s.	1.540	0.096	0.068	0.021	0.058	0.033	0.154	0.327	0.783
Feed input value	3.366	0.460	0.336	0.068	0.129	0.146	0.987	0.649	0.591
Non-agricultural input value	0.500	0.041	0.050	0.007	0.027	0.014	0.039	0.087	0.234
Gross value added	10.613	0.663	0.832	0.145	0.646	0.241	0.127	1.872	6.086
Labour remuneration	3.067	0.247	0.163	0.053	0.176	0.089	0.255	0.568	1.516
Gross operating surplus	7.545	0.416	0.669	0.092	0.470	0.152	-0.128	1.305	4.570
== Trad.mixed ruminant farm ==									
Value of meat, milk and eggs	32.408	14.188	3.797	3.117	1.435	0.791	3.188	0.681	5.211
Manure output value	4.209	1.578	0.559	0.321	0.141	0.134	0.758	0.041	0.677
Output value n.e.s.	4.809	1.999	0.479	0.462	0.185	0.117	0.540	0.114	0.913
Feed input value	37.982	19.345	3.950	4.360	1.027	1.126	4.558	0.795	2.820
Non-agricultural input value	1.355	0.544	0.177	0.125	0.059	0.036	0.153	0.029	0.232
Gross value added	2.088	-2.124	0.707	-0.585	0.675	-0.120	-0.226	0.013	3.748
Labour remuneration	9.621	4.496	0.756	1.044	0.386	0.232	0.976	0.186	1.545
Gross operating surplus	-7.533	-6.620	-0.049	-1.628	0.289	-0.352	-1.202	-0.173	2.203

Types of livestock raising in billion Yuan (continued)

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Specialized dairy farm ==									
Value of meat, milk and eggs	4.559	1.500	1.255	0.786	0.075	0.238	0.134	0.023	0.549
Manure output value	0.074	0.018	0.034	0.006	0.001	0.003	0.002	0.000	0.010
Output value n.e.s.	0.046	0.015	0.013	0.008	0.001	0.002	0.001	0.000	0.006
Feed input value	0.982	0.292	0.375	0.124	0.015	0.039	0.025	0.006	0.105
Non-agricultural input value	0.565	0.193	0.145	0.093	0.011	0.029	0.019	0.003	0.074
Gross value added	3.133	1.048	0.783	0.582	0.051	0.175	0.093	0.014	0.386
Labour remuneration	0.383	0.105	0.127	0.073	0.006	0.019	0.012	0.002	0.040
Gross operating surplus	2.750	0.944	0.655	0.510	0.045	0.156	0.081	0.012	0.346
== Trad.mixed nonruminant farm ==									
Value of meat, milk and eggs	311.865	68.367	24.595	41.897	51.222	44.915	64.665	0.631	15.573
Manure output value	7.509	1.696	0.642	0.753	0.939	0.877	2.277	0.006	0.320
Feed input value	146.457	28.220	12.298	15.982	23.460	16.261	43.666	0.326	6.243
Non-agricultural input value	11.120	1.808	0.822	1.095	1.858	1.819	2.964	0.024	0.729
Gross value added	161.797	40.035	12.116	25.573	26.842	27.713	20.311	0.287	8.921
Labour remuneration	62.926	11.901	3.491	6.600	9.798	10.031	17.753	0.120	3.232
Gross operating surplus	98.871	28.134	8.625	18.973	17.045	17.681	2.557	0.168	5.689
== Intensified nonruminant farm ==									
Value of meat, milk and eggs	123.023	28.138	13.441	22.641	14.646	24.953	15.275	0.091	3.838
Manure output value	1.894	0.482	0.238	0.262	0.200	0.317	0.333	0.001	0.062
Feed input value	54.602	12.552	6.895	10.116	7.481	8.591	7.018	0.057	1.892
Non-agricultural input value	26.819	6.202	2.759	4.966	3.195	5.386	3.382	0.020	0.910
Gross value added	43.495	9.866	4.025	7.821	4.169	11.294	5.208	0.015	1.098
Labour remuneration	6.416	1.539	0.575	1.191	0.848	1.165	0.892	0.005	0.201
Gross operating surplus	37.079	8.327	3.450	6.629	3.321	10.129	4.316	0.010	0.897

Non-farm production in billion Yuan

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Fish ==									
Value of intermediate input	39.654	9.694	5.158	11.904	4.620	5.772	1.936	0.002	0.568
Gross value added	115.840	19.233	8.032	32.083	12.319	39.237	4.217	0.017	0.701
Production value	155.494	28.927	13.191	43.988	16.939	45.008	6.152	0.019	1.268
== Forest products ==									
Value of intermediate input	31.260	5.602	2.351	6.081	3.167	9.447	2.375	0.053	2.183
Gross value added	49.122	8.135	1.618	7.141	9.906	11.177	8.370	0.127	2.647
Production value	80.382	13.737	3.970	13.221	13.073	20.625	10.746	0.181	4.830
== Industry and construction ==									
Value of intermediate input	9655.811	2310.743	872.953	2920.479	902.836	1762.783	545.712	15.442	324.865
Gross value added	3745.130	938.111	375.770	909.477	352.751	622.716	331.063	9.685	205.557
Production value	13400.941	3248.854	1248.723	3829.956	1255.587	2385.499	876.775	25.126	530.422
== Services ==									
Value of intermediate input	2453.259	602.253	232.304	622.455	230.968	478.563	159.548	7.689	119.478
Gross value added	2791.454	737.599	258.390	601.697	275.501	470.711	255.155	11.853	180.547
Production value	5244.713	1339.852	490.694	1224.153	506.469	949.275	414.703	19.541	300.025

Regional value added (billion Yuan)

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
Irrigated cropping	476.12	120.71	20.04	111.10	84.70	48.35	47.65	1.20	42.37
Rainfed cropping	247.33	29.51	40.00	26.82	30.96	42.77	59.57	1.38	16.32
Tree cropping	35.25	13.24	1.19	3.11	1.62	9.79	2.37	0.02	3.90
Cropping sector	758.71	163.45	61.23	141.04	117.29	100.91	109.59	2.59	62.60
Draught animal system	21.91	-3.32	-0.88	1.52	11.23	6.56	5.88	0.06	0.86
Grazing system	10.61	0.66	0.83	0.14	0.65	0.24	0.13	1.87	6.09
Trad.mixed ruminant farm	2.09	-2.12	0.71	-0.58	0.67	-0.12	-0.23	0.01	3.75
Specialized dairy farm	3.13	1.05	0.78	0.58	0.05	0.18	0.09	0.01	0.39
Trad.mixed nonruminant farm	161.80	40.03	12.12	25.57	26.84	27.71	20.31	0.29	8.92
Intensified nonruminant farm	43.50	9.87	4.03	7.82	4.17	11.29	5.21	0.01	1.10
Livestock sector	243.03	46.17	17.58	35.06	43.61	45.87	31.39	2.26	21.10
Fish and forestry	164.96	27.37	9.65	39.22	22.22	50.41	12.59	0.14	3.35
Non-agriculture	6536.58	1675.71	634.16	1511.17	628.25	1093.43	586.22	21.54	386.10
Non-farm sector	6701.55	1703.08	643.81	1550.40	650.48	1143.84	598.80	21.68	389.45
Total	7703.29	1912.70	722.62	1726.49	811.37	1290.62	739.79	26.54	473.15

Regional budgets (billion Yuan)

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
Value added	7703.22	1912.68	722.62	1726.46	811.38	1290.62	739.78	26.54	473.15
Agricultural producer tax	140.75	32.44	12.04	23.08	19.72	21.36	21.57	0.66	9.87
Agricultural consumer tax	10.56	2.09	0.97	2.46	1.07	2.25	1.09	0.04	0.60
Agricultural trade tax	8.06	4.04	-1.87	2.39	0.00	3.51	0.00	0.00	0.00
Income	7862.59	1951.24	733.75	1754.38	832.18	1317.74	762.45	27.23	483.62
Private consumption value	4067.87	869.01	320.74	851.30	467.36	822.52	478.08	17.08	241.78
Public consumption value	927.00	254.15	97.02	150.56	93.77	174.28	83.32	4.72	69.18
Trade and transport losses	91.11	19.72	8.14	16.96	12.81	16.93	11.13	0.35	5.06
Investment value	2531.66	649.20	200.52	650.62	228.50	427.66	211.33	12.56	151.27
Net stock increases	-90.74	-22.01	-10.40	-22.02	-8.29	-15.54	-8.00	-0.12	-4.37
Expenditures	7526.89	1770.07	616.02	1647.41	794.16	1425.86	775.87	34.59	462.91
Income surplus	335.70	181.18	117.73	106.98	38.01	-108.12	-13.43	-7.35	20.70

Foreign trade values and taxes (billion Yuan)

	Import cif	Import tax	Export fob	Export tax	Net import	Total tax
Milled rice	0.000	0.000	1.555	0.115	-1.555	0.115
Wheat flour	1.529	0.076	0.000	0.000	1.529	0.076
Maize	0.000	0.000	6.834	-3.216	-6.834	-3.216
Other staple food	1.174	0.294	0.000	0.000	1.174	0.294
Vegetable oil	10.390	4.883	0.000	0.000	10.390	4.883
Sugar	0.923	0.462	0.000	0.000	0.923	0.462
Fruits	0.000	0.000	0.994	0.090	-0.994	0.090
Vegetables	0.000	0.000	14.968	1.361	-14.968	1.361
Ruminant meat	0.000	0.000	1.253	0.093	-1.253	0.093
Pork	0.000	0.000	5.121	0.853	-5.121	0.853
Poultry meat	0.000	0.000	4.123	0.262	-4.123	0.262
Milk	0.012	0.003	0.000	0.000	0.012	0.003
Eggs	0.000	0.000	0.583	0.022	-0.583	0.022
Fish	0.000	0.000	21.168	2.761	-21.168	2.761
Non-food excl feed	0.000	0.000	299.207	0.000	-299.207	0.000
Carbohydrate feed	0.123	0.000	0.000	0.000	0.123	0.000
Protein feed	5.938	0.000	0.000	0.000	5.938	0.000
All commodities	20.089	5.718	355.805	2.343	-335.716	8.060

Consumer prices (Yuan per kg)

	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Milled rice ==								
Rural low income	2.608	2.102	2.013	1.851	2.368	2.280	2.873	2.359
Rural middle income	2.745	2.213	2.119	1.948	2.492	2.400	3.024	2.484
Rural high income	3.130	2.523	2.416	2.221	2.841	2.736	3.447	2.831
Urban low income	2.834	2.336	2.320	2.150	2.918	2.693	3.333	2.707
Urban middle income	2.983	2.459	2.442	2.263	3.071	2.835	3.508	2.849
Urban high income	3.579	2.951	2.930	2.716	3.686	3.401	4.210	3.419
== Wheat flour ==								
Rural low income	1.820	1.635	1.736	1.772	1.991	1.841	1.967	1.850
Rural middle income	1.916	1.721	1.827	1.866	2.096	1.938	2.070	1.947
Rural high income	2.184	1.961	2.083	2.127	2.390	2.209	2.360	2.220
Urban low income	2.239	2.305	2.379	2.687	3.307	2.308	2.395	2.123
Urban middle income	2.357	2.427	2.504	2.828	3.481	2.429	2.521	2.235
Urban high income	2.828	2.912	3.005	3.394	4.177	2.915	3.026	2.682
== Maize ==								
Rural low income	1.118	1.336	1.382	1.540	1.420	1.362	1.408	1.268
Rural middle income	1.177	1.406	1.455	1.621	1.495	1.433	1.482	1.334
Rural high income	1.341	1.603	1.658	1.848	1.704	1.634	1.689	1.521
Urban low income	1.296	1.627	1.994	2.012	1.846	1.783	1.857	1.540
Urban middle income	1.364	1.712	2.099	2.117	1.943	1.877	1.955	1.621
Urban high income	1.637	2.055	2.519	2.541	2.331	2.252	2.346	1.946

Consumer prices (Yuan per kg) (continued)

	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Other staple food ==								
Rural low income	3.276	3.760	3.734	3.642	4.492	3.992	4.091	3.825
Rural middle income	3.276	3.760	3.734	3.642	4.492	3.992	4.091	3.825
Rural high income	3.276	3.760	3.734	3.642	4.492	3.992	4.091	3.825
Urban low income	3.857	4.202	4.637	4.057	5.113	4.691	4.768	4.586
Urban middle income	3.857	4.202	4.637	4.057	5.113	4.691	4.768	4.586
Urban high income	3.857	4.202	4.637	4.057	5.113	4.691	4.768	4.586
== Vegetable oil ==								
Rural low income	8.053	7.379	7.801	7.700	10.840	7.701	7.602	7.868
Rural middle income	8.053	7.379	7.801	7.700	10.840	7.701	7.602	7.868
Rural high income	8.053	7.379	7.801	7.700	10.840	7.701	7.602	7.868
Urban low income	9.205	8.130	9.430	9.269	13.781	9.098	8.391	8.769
Urban middle income	9.205	8.130	9.430	9.269	13.781	9.098	8.391	8.769
Urban high income	9.205	8.130	9.430	9.269	13.781	9.098	8.391	8.769
== Sugar ==								
Rural low income	3.996	4.385	4.117	3.941	4.002	3.976	4.619	4.078
Rural middle income	3.996	4.385	4.117	3.941	4.002	3.976	4.619	4.078
Rural high income	3.996	4.385	4.117	3.941	4.002	3.976	4.619	4.078
Urban low income	4.516	4.845	4.675	4.487	4.997	4.489	5.205	4.502
Urban middle income	4.516	4.845	4.675	4.487	4.997	4.489	5.205	4.502
Urban high income	4.516	4.845	4.675	4.487	4.997	4.489	5.205	4.502
== Fruits ==								
Rural low income	1.287	1.512	1.590	1.531	2.494	1.746	1.728	1.129
Rural middle income	1.355	1.591	1.673	1.611	2.625	1.838	1.819	1.188
Rural high income	1.545	1.814	1.908	1.837	2.992	2.096	2.074	1.354
Urban low income	2.033	2.117	3.034	2.549	6.049	2.934	2.289	1.940
Urban middle income	2.140	2.228	3.193	2.683	6.367	3.089	2.409	2.042
Urban high income	2.567	2.674	3.832	3.220	7.640	3.706	2.891	2.450

Consumer prices (Yuan per kg) (continued)

	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Vegetables ==								
Rural low income	0.932	1.095	1.870	1.797	1.952	1.326	1.014	0.903
Rural middle income	0.932	1.095	1.870	1.797	1.952	1.326	1.014	0.903
Rural high income	0.932	1.095	1.870	1.797	1.952	1.326	1.014	0.903
Urban low income	1.476	1.391	3.217	2.215	3.383	1.751	1.761	1.354
Urban middle income	1.476	1.391	3.217	2.215	3.383	1.751	1.761	1.354
Urban high income	1.476	1.391	3.217	2.215	3.383	1.751	1.761	1.354
== Ruminant meat ==								
Rural low income	10.849	9.988	12.540	10.270	11.075	9.818	8.589	9.925
Rural middle income	11.420	10.514	13.200	10.811	11.658	10.334	9.041	10.447
Rural high income	13.019	11.985	15.049	12.325	13.290	11.781	10.307	11.910
Urban low income	12.562	11.541	16.740	12.443	17.273	12.052	9.827	11.503
Urban middle income	13.223	12.149	17.621	13.098	18.182	12.687	10.344	12.109
Urban high income	15.867	14.578	21.145	15.717	21.818	15.224	12.413	14.530
== Pork ==								
Rural low income	11.472	10.441	12.580	11.042	13.202	10.215	10.567	10.017
Rural middle income	12.075	10.991	13.242	11.624	13.897	10.752	11.123	10.544
Rural high income	13.766	12.529	15.096	13.251	15.843	12.258	12.680	12.020
Urban low income	13.253	12.288	15.443	14.096	18.722	11.444	11.719	11.493
Urban middle income	13.950	12.935	16.256	14.838	19.707	12.046	12.336	12.098
Urban high income	16.740	15.522	19.507	17.805	23.648	14.455	14.803	14.518
== Poultry meat ==								
Rural low income	11.295	11.962	13.728	13.394	17.341	16.321	15.138	12.381
Rural middle income	11.890	12.592	14.451	14.099	18.254	17.180	15.935	13.033
Rural high income	13.554	14.354	16.474	16.073	20.809	19.585	18.166	14.857
Urban low income	14.876	13.534	21.158	20.176	22.223	19.329	17.241	16.051
Urban middle income	15.659	14.246	22.271	21.238	23.392	20.346	18.148	16.896
Urban high income	18.791	17.095	26.726	25.486	28.071	24.416	21.778	20.276

Consumer prices (Yuan per kg) (continued)

	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Milk ==								
Rural low income	3.183	2.771	3.071	4.323	4.779	4.749	2.896	2.631
Rural middle income	3.183	2.771	3.071	4.323	4.779	4.749	2.896	2.631
Rural high income	3.183	2.771	3.071	4.323	4.779	4.749	2.896	2.631
Urban low income	3.985	3.494	4.045	5.537	5.937	5.936	3.620	3.212
Urban middle income	3.985	3.494	4.045	5.537	5.937	5.936	3.620	3.212
Urban high income	3.985	3.494	4.045	5.537	5.937	5.936	3.620	3.212
== Eggs ==								
Rural low income	5.765	6.108	6.569	7.636	8.441	7.854	6.679	6.038
Rural middle income	5.765	6.108	6.569	7.636	8.441	7.854	6.679	6.038
Rural high income	5.765	6.108	6.569	7.636	8.441	7.854	6.679	6.038
Urban low income	6.417	6.840	7.525	8.355	9.281	9.620	7.538	7.480
Urban middle income	6.417	6.840	7.525	8.355	9.281	9.620	7.538	7.480
Urban high income	6.417	6.840	7.525	8.355	9.281	9.620	7.538	7.480
== Fish ==								
Rural low income	6.685	7.192	7.542	6.086	8.737	8.900	5.526	6.875
Rural middle income	6.685	7.192	7.542	6.086	8.737	8.900	5.526	6.875
Rural high income	6.685	7.192	7.542	6.086	8.737	8.900	5.526	6.875
Urban low income	9.596	7.439	14.954	9.103	13.919	11.072	8.721	9.411
Urban middle income	9.596	7.439	14.954	9.103	13.919	11.072	8.721	9.411
Urban high income	9.596	7.439	14.954	9.103	13.919	11.072	8.721	9.411
== Non-food excl feed ==								
Rural low income	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Rural middle income	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Rural high income	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Urban low income	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Urban middle income	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000
Urban high income	10.000	10.000	10.000	10.000	10.000	10.000	10.000	10.000

Budget shares in percentages

	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Wheat, rice and maize ==								
Rural low income	27.943	18.991	24.260	24.305	24.888	37.915	29.500	32.488
Rural middle income	22.527	16.633	16.398	21.185	18.743	29.427	25.654	27.063
Rural high income	17.012	14.792	8.910	18.404	12.352	23.736	19.241	20.061
Urban low income	11.706	12.392	7.490	10.637	12.800	9.906	13.517	12.602
Urban middle income	6.261	8.290	5.444	6.601	8.077	5.818	8.482	8.683
Urban high income	4.840	5.770	4.482	4.702	3.854	4.593	6.032	5.704
== Other staple, oil and sugar ==								
Rural low income	8.628	9.572	7.837	7.712	6.248	7.048	21.588	10.642
Rural middle income	7.617	8.756	6.217	7.218	5.537	6.833	19.361	9.458
Rural high income	6.686	7.906	4.278	6.589	4.403	6.076	15.031	7.363
Urban low income	4.868	5.681	4.786	5.568	4.903	4.738	6.387	6.342
Urban middle income	3.913	4.097	4.013	4.655	3.867	3.893	5.189	5.258
Urban high income	3.302	3.278	3.465	3.569	2.922	3.306	3.630	4.026
== Vegetables and fruits ==								
Rural low income	11.232	11.096	11.423	14.944	12.853	12.214	10.269	7.070
Rural middle income	11.451	12.910	11.578	15.060	11.814	14.370	11.240	7.625
Rural high income	10.130	11.939	10.397	13.921	10.614	12.679	12.300	8.151
Urban low income	11.253	13.681	11.660	13.211	11.540	11.806	11.632	11.640
Urban middle income	10.552	12.394	10.609	11.623	10.240	10.608	10.938	11.231
Urban high income	9.273	10.735	9.560	9.254	8.392	9.428	9.240	9.000

Budget shares in percentages (continued)

	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Meat, milk and eggs ==								
Rural low income	12.397	12.362	14.505	15.762	17.924	21.943	15.635	11.085
Rural middle income	13.482	13.189	14.704	15.146	16.937	21.882	17.995	12.822
Rural high income	13.945	13.037	10.128	14.768	12.951	21.817	18.459	14.330
Urban low income	19.973	19.868	24.110	22.762	26.110	25.408	18.644	18.900
Urban middle income	19.561	19.080	21.064	20.848	22.670	21.619	18.562	19.445
Urban high income	17.834	17.891	18.075	17.094	15.559	18.352	15.388	16.220
== Fish ==								
Rural low income	1.204	1.972	2.607	1.733	3.105	0.609	0.290	0.344
Rural middle income	1.467	2.048	3.462	2.141	4.055	0.773	0.600	0.476
Rural high income	1.930	2.034	5.082	2.460	5.297	1.039	1.240	0.685
Urban low income	3.831	3.710	8.954	5.554	8.146	3.694	1.040	2.716
Urban middle income	4.656	3.863	10.518	5.159	7.046	3.724	1.310	3.231
Urban high income	4.199	4.054	10.119	4.321	5.352	3.166	1.110	2.950
== Non-food ==								
Rural low income	38.595	46.008	39.368	35.544	34.982	20.271	22.718	38.372
Rural middle income	43.456	46.465	47.642	39.250	42.915	26.715	25.150	42.556
Rural high income	50.296	50.292	61.206	43.859	54.384	34.653	33.729	49.410
Urban low income	48.368	44.669	43.000	42.269	36.500	44.448	48.780	47.800
Urban middle income	55.058	52.276	48.352	51.114	48.100	54.338	55.519	52.152
Urban high income	60.553	58.271	54.300	61.060	63.922	61.154	64.600	62.100
== Total commodities ==								
Rural low income	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Rural middle income	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Rural high income	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Urban low income	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Urban middle income	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000
Urban high income	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

Household indicators

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Rural low income ==									
Population in millions	273.67	69.94	17.31	38.40	38.41	32.90	49.35	1.93	25.43
Consumption value in Y/cap	1331.52	1203.01	1617.36	1640.18	1428.23	1825.55	999.09	912.49	916.03
Grain consumption (kg/cap)	185.54	187.22	170.59	207.27	188.67	194.47	177.66	130.73	161.42
Meat+egg consumption(kg/cap)	18.95	16.03	21.83	20.66	20.76	23.65	20.98	11.24	10.30
Energy intake (Kcal/cap/day)	2389.76	2425.89	2472.95	2682.59	2455.31	2450.87	2173.75	2113.64	2053.68
== Rural middle income ==									
Population in millions	273.67	69.94	17.31	38.40	38.41	32.90	49.35	1.93	25.43
Consumption value in Y/cap	1853.32	1597.65	1954.57	2500.92	1867.51	2751.61	1417.51	1217.06	1220.08
Grain consumption (kg/cap)	192.26	190.26	171.54	203.28	204.31	210.01	185.90	144.05	170.03
Meat+egg consumption(kg/cap)	25.77	22.46	27.22	30.71	24.95	32.13	28.31	16.37	15.20
Energy intake (Kcal/cap/day)	2613.71	2589.58	2620.79	2845.78	2755.43	2796.49	2426.57	2444.60	2250.32
== Rural high income ==									
Population in millions	273.67	69.94	17.31	38.40	38.41	32.90	49.35	1.93	25.43
Consumption value in Y/cap	3103.62	2643.70	2744.47	5055.18	2660.08	4739.58	2252.91	1953.22	1957.49
Grain consumption (kg/cap)	204.27	208.28	187.89	196.56	221.80	209.66	209.08	152.10	177.24
Meat+egg consumption(kg/cap)	35.23	35.63	34.75	38.80	31.00	37.55	39.82	23.67	24.44
Energy intake (Kcal/cap/day)	3014.22	3090.67	3028.32	3176.69	3142.13	3066.50	2896.24	2853.28	2529.45
== Rural population ==									
Population in millions	821.01	209.82	51.92	115.21	115.22	98.70	148.06	5.78	76.30
Consumption value in Y/cap	2096.15	1814.79	2105.47	3065.43	1985.27	3105.58	1556.50	1360.92	1364.53
Grain consumption (kg/cap)	194.02	195.25	176.68	202.37	204.93	204.72	190.88	142.29	169.56
Meat+egg consumption(kg/cap)	26.65	24.70	27.93	30.06	25.57	31.11	29.70	17.09	16.65
Energy intake (Kcal/cap/day)	2672.56	2702.05	2707.35	2901.68	2784.29	2771.29	2498.85	2470.51	2277.82

Household indicators (continued)

	China	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
== Urban low income ==									
Population in millions	141.20	31.50	16.86	25.61	16.24	23.80	15.63	0.64	10.92
Consumption value in Y/cap	2994.22	2663.98	2524.53	3861.21	2643.19	3037.34	3385.88	2878.11	2513.19
Grain consumption (kg/cap)	132.07	135.16	137.82	124.46	127.06	132.57	130.60	153.33	139.37
Meat+egg consumption(kg/cap)	47.59	42.50	42.22	57.47	42.55	43.33	65.44	45.55	38.76
Energy intake (Kcal/cap/day)	2180.86	2167.39	2262.07	2266.35	2086.43	1987.52	2307.83	2476.20	2256.80
== Urban middle income ==									
Population in millions	141.20	31.50	16.86	25.61	16.24	23.80	15.63	0.64	10.92
Consumption value in Y/cap	4960.46	4768.97	3645.70	6319.91	4235.81	5621.60	5172.92	4268.76	3727.55
Grain consumption (kg/cap)	129.86	121.89	127.01	140.44	118.33	146.48	114.28	135.04	135.33
Meat+egg consumption(kg/cap)	68.68	71.60	56.41	78.73	59.89	66.48	80.58	64.47	56.65
Energy intake (Kcal/cap/day)	2520.77	2523.60	2332.81	2859.76	2322.20	2483.89	2425.42	2581.10	2516.46
== Urban high income ==									
Population in millions	141.20	31.50	16.86	25.61	16.24	23.80	15.63	0.64	10.92
Consumption value in Y/cap	8667.05	8065.74	6371.06	9270.79	7811.34	13020.95	7286.24	7294.17	6369.36
Grain consumption (kg/cap)	130.42	133.52	129.47	141.22	128.52	133.97	106.57	135.06	126.60
Meat+egg consumption(kg/cap)	86.15	97.45	81.20	86.05	79.03	89.83	82.02	79.02	70.33
Energy intake (Kcal/cap/day)	2972.26	3171.87	2816.18	3195.26	2875.74	3043.42	2510.91	2860.10	2769.65
== Urban population ==									
Population in millions	423.59	94.50	50.58	76.82	48.73	71.40	46.88	1.92	32.75
Consumption value in Y/cap	5540.58	5166.23	4180.43	6483.97	4896.78	7226.63	5281.68	4813.68	4203.37
Grain consumption (kg/cap)	130.78	130.19	131.43	135.38	124.63	137.68	117.15	141.14	133.77
Meat+egg consumption(kg/cap)	67.47	70.52	59.94	74.08	60.49	66.55	76.01	63.01	55.24
Energy intake (Kcal/cap/day)	2557.96	2620.95	2470.35	2773.79	2428.12	2504.94	2414.72	2639.13	2514.30
== National population ==									
Population in millions	1244.60	304.33	102.49	192.04	163.95	170.10	194.95	7.69	109.05
Consumption value in Y/cap	3268.43	2855.51	3129.36	4433.00	2850.61	4835.49	2452.40	2220.31	2217.15
Grain consumption (kg/cap)	172.50	175.05	154.35	175.57	181.06	176.57	173.15	142.01	158.81
Meat+egg consumption(kg/cap)	40.54	38.93	43.73	47.67	35.95	45.99	40.84	28.52	28.24
Energy intake (Kcal/cap/day)	2633.56	2676.86	2590.40	2850.52	2678.43	2659.48	2478.62	2512.48	2348.84