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with the Chinagro welfare model
covering national, regional and county level

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Preface

This report describes simulations of the future of China's agricultural economy with the Chinagro welfare model. The model was originally constructed in the period 2002-2004 as part of the EC-funded Fifth Framework project of the same name, with support of the Natural Science Foundation of China (#70024001), and has been developed further in 2006 and 2007 under the follow-up project 'Options for Agricultural Development in China' funded by the Netherlands Ministry of Agriculture, Nature Management and Food Quality.

At the same time, the publication of this report marks the beginning of the modeling activities in the CATSEI-project, an EC-funded Sixth Framework project started in January 2007, of which the three research themes (Trade, Social and Environment) can easily be recognized in the presentation of the current simulations. The Chinagro model will be updated and extended under CATSEI, integrating the research results on its three themes.

Five partner institutes cooperated in the Chinagro project: the International Institute for Applied Systems Analysis (IIASA), Laxenburg, Austria; the Centre for World Food Studies (SOW-VU), Vrije Universiteit, Amsterdam, The Netherlands; the Center for Chinese Agricultural Policy (CCAP), Chinese Academy of Sciences, Beijing; the Institute for Geographical Sciences and Natural Resources Research (IGSNRR), Chinese Academy of Sciences, Beijing; and the China Agricultural University (CAU), also in Beijing. The first three institutes have extended their cooperation in the CATSEI-project, together with the School of Oriental and African Studies (SOAS) of the University of London, the International Food Policy Research Institute (IFPRI) in Washington and the Agricultural Economics Research Institute (LEI) in The Hague.

We acknowledge the contributions of several of our colleagues and project partners in obtaining the results presented in this report, in the form of consultations, background studies, technical assistance and logistic support. We mention especially Peter Albersen (SOW-VU), Chen Fu (CAU) and Xiubin Li (IGSNRR).

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Abstract

The report describes prospects and challenges for Chinese agriculture until 2030 under different scenarios, using the Chinagro welfare model. A scenario is defined as a coherent set of assumptions about exogenous driving forces (farm land, population, non-agricultural growth, world prices etc.), derived from the literature and own assessments. Under these assumptions, simulations with the Chinagro model analyze the price-based interaction between the supply behavior of farmers, the demand behavior of consumers and the determination of trade flows by merchants.

The outcomes from the *Baseline scenario* seem reassuring in that foreign imports remain moderate relative to China's size, though quite large as fraction of world trade. It would be possible to feed people as well as animals without excessive imports. There is even a potential for significant export flows of vegetables and fruits. Regarding concerns, the trends in per capita agricultural value added are problematic, because they stay in all regions behind per capita value added outside agriculture, albeit that they are rising steadily. This leads to growing disparity in per capita incomes within and across regions. The mounting environmental pressure from fertilizer losses and unused manure surpluses is another cause of concern. The second scenario, the *Trade liberalization scenario,* appears to hurt farm incomes more than it benefits them and to raise the gap with non-agriculture, also because food becomes cheaper in urban areas. Hence, it highlights the difficult choice between economic efficiency and poverty alleviation that agricultural policy makers often face. The *High income growth scenario* reinforces the national food self-sufficiency result of the baseline simulation. Even with meat demand higher than under the baseline, levels of imports remain manageable. The *High R&D scenario* shows that a considerable reduction in dependence on agricultural imports is possible. However, a substantial part of the gains will accrue to consumers rather than to farmers, due to price reductions. Finally, the *Enhanced irrigation scenario* shows outcomes similar to those of the high R&D scenario. Here also the agricultural trade balance improves and consumer welfare improves, but farmers have to cope with drops in prices, and those who do not benefit from land improvement, only experience losses through falling prices.

The present report is written at the onset of the CATSEI-project that will analyze policy packages with more specificity and detail after implementing the following model improvements. First, the impact of China's imports and exports on world markets will be represented explicitly. Second, the developments outside agriculture in rural areas will be accounted for endogenously, particularly to represent farm revenue from off-farm employment. Third, the trade and transportation margins between farm-gates and markets will be made dependent on the relative flexibility of the actors (farmers, processors, traders) along the chain. Finally, the various techniques to identify more efficient and more sustainable use of scarce water and nutrients and to address health risks will appear more explicitly.

1. Introduction

China's unprecedented economic growth since the start of the reform program in 1978 and the gradual liberalization of its trade have dramatically improved the living conditions in rural areas, largely through increased off-farm employment but also through significant productivity gains within the crop sector and further specialization of farms particularly toward livestock production and horticulture. Only 8 percent of the rural population was reported as being below the international poverty line[1] in 2004, down from 31 percent in 1990 (NBSCb, various issues). However, already since the 1980s the rural to urban income gap has gradually widened, from a ratio of less than 2.5 in the middle 1980s to nearly 3.5 currently (NBSCa, various issues). Containing this aspect of income disparity requires spreading industrial development inland, while ensuring modernization of agriculture itself so as to combine sustainable rural development with the necessary adjustment of the agricultural sector to the further opening for trade, in particular since the nation's accession to the World Trade Organization (WTO) in December 2001, and to emerging scarcity on international agricultural markets. After decades of surpluses food availability is expected to become tighter as a result of continued economic growth in Asia and the associated rise in demand for food and animal feeds, jointly with upcoming demand for biofuels and, over the medium term, the impact of climate change and the associated adaptation and mitigation policies worldwide. Hence, prolongation of current success will require several issues to be attended to simultaneously.

Continued trade liberalization should 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. However, it will also necessitate 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. 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, water shortages and exhaustion of the unused potential for yield increases on the basis of conventional technology. At the same time, farmers will face increasingly strict regulations to mitigate the environmental and health risks of intensified agriculture. Given these restrictions, farmers are left with three options: modernizing staple crop production, switching to higher value products such as livestock and horticulture, or seeking employment outside the sector.

Policy response

In response to these challenges, the Chinese government (CPC, 2003) has formulated as its major strategic and policy aims: (i) to increase farmers' incomes and provide remunerative rural employment, so as to maintain social stability at the local level; (ii) to narrow regional and rural versus urban disparity, so as to preserve political stability at national level; (iii) to improve resource use efficiency and product quality, so as to obtain the economic sustainability needed to face foreign competition; (iv) to arrest environmental degradation, so as to retain environmental sustainability; and (v) to keep an adequate degree 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 widely accepted, the ways and means to achieve them are still subject to intense debate. With respect to national food security, the basic question seems no longer to be whether China can produce sufficient amounts of rice

[1] Defined as one US dollar of 1993 per day per person, converted into Yuan using the World Bank's Purchasing Power Parity exchange rate.

and wheat for its vast population but whether it can feed the vast number of animals required to satisfy the rapidly increasing demand for meat, and, if not, whether it should import meat or import feed or import both. Furthermore, China's huge population comprises numerous ethnic nationalities spread over a vast territory of complex geography and topography. Consequently, every region has its own geographical, ecological, and socio-economic specificity. This implies that an effective nationwide policy needs a diverse and well-adapted development package, based on a thorough understanding of the underlying diversity. In this context, an optimal mix is to be found between public and private actions as the competitive market is in many respects better equipped to address diversity than any other institution.

However, despite the ongoing process of decentralization and trade liberalization, a number of key market institutions are still underdeveloped. On the commodity markets, those related to product grading and consumer protection leave to be desired. On agricultural factor markets, better titling of land is necessary, water management needs to become more efficient, and environmental protection should receive higher priority. Safety regulations for workers would be required and workers' health and education need to be attended to, while supervision of banking and insurance must ensure that agriculture receives sufficient credit while avoiding poor debt service and bad loans. Furthermore, income transfers will surely be needed in order to contain income disparity across regions and between rural and urban areas. Moreover, 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 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 to foreign investors worldwide.

Hence, government agencies at both national and provincial level will have to draft transparent policy documents in which sufficient motivation is provided for each policy measure taken, in particular to demonstrate that the interventions proposed are necessary, not overly centralized and answering to the local needs of every province.

The present paper intends to contribute to this process of policy design. It reports on scenario simulations with the Chinagro-model, originally developed under the EC-funded Fifth Framework project of the same name, and adapted further under 'Options for Agricultural Development in China', the follow-up project funded by the Netherlands Ministry of Agriculture, Nature Management and Food Quality. It will be updated and extended under CATSEI, an EC-funded Sixth Framework project devoted to studying the prospects of agricultural trade between China and the EU. These projects seek to offer science-based decision support tools that can help in the formulation of adequate policy packages to facilitate the continued modernization of Chinese agriculture and the smooth development of trade relations with foreign partners. Against the background sketched above, these tools had to be designed so as to represent the following five aspects of agricultural planning in sufficient detail:

(1) the constraints of geophysical and natural resource conditions on agriculture production,
(2) the market forces determining the distribution of agricultural activities,
(3) the spatial spread and social diversity of China's population,
(4) the impacts of policy on farm incomes and on regional disparity,
(5) the environmental impacts of agriculture.

Literature

As these five aspects are well recognized, the literature considering them is extensive. It essentially falls in two parts, one the domain of agronomists and economic geographers describing the geo-physical and natural resource conditions in each region, the other the domain of agricultural economists comparing production costs across regions.

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, length of crop growing period etc. Based on the assessment of these factors, suggestions are 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 extend this approach into a comprehensive spatial assessment of the impact of the natural resource constraints on agricultural production, for example by means of FAO's Agro-Ecological Zones (AEZ) methodology (Fischer et al., 2002).

This AEZ-methodology can be used to identify the geophysical limitations on agriculture production within every region, and to formulate options for more efficient use of the local natural resources, and in fact provides one of the major inputs of the Chinagro-model. However, while agriculture production undeniably depends on the available natural resources and environmental conditions, describing agricultural potentials is only a first step. Regional development planning has to go several steps further, as agriculture is conducted by farmers using inputs provided by industry and delivering outputs 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. Furthermore, 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 who focus on comparing production costs across regions, we cite Huang and Ma (2001) and Xu et al. (2001). These two works use 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 between regions for, say, labor and fertilizer. However, it only measures the present situation. It can at best provide a useful guideline on the direction of agricultural restructuring because any actual restructuring would change the prices and intensities in every region. A decision support tool must be able to account for these 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 may not be able to realize these advantages fully as high transportation cost, inter-regional trade barriers, and other trade costs can offset all of them. Young (2000) and Hussain (2004) point 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 to take the supply, demand and trade aspects simultaneously into consideration. Huang and Rozelle (2003) and Huang, Li and Rozelle (2003) use the CAPSiM regional model, a partial equilibrium model with 18 agricultural commodities, to analyze the impacts of WTO accession on agricultural production and consumption and on farm incomes in different provinces across China. These studies show that while trade liberalization will stimulate structural changes of China's agriculture in favor of its more competitive sector (i.e. labor-intensive agricultural products) and increase the average farming income, it will also enlarge income disparity among regions. However, the CAPSiM model does not fully consider resource constraints, such as water and land availability, existing at local level. Xin et al. (2002 and 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 modeled and simulated independently it cannot handle the interactions between grain and livestock sectors. Neither does it consider the local resource constraints in each region.

The Chinagro models

The importance of the five 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, and the other commodity-specific but spatially explicit.

The comprehensive model is a 17-commodity, 8-region general equilibrium welfare model. Farm supply is represented at the level of 2,433 counties (virtually all), and accommodates for every county outputs of 28 products and 14 land use types and livestock systems. Consumption is depicted at regional level, separately for the urban and the rural population, each divided into three income groups, and domestic trade is interregional. The model structure is described in Keyzer and Van Veen (2005), while a comprehensive list of classifications and the data base are documented in Van Veen et al. (2005).

The model describes the price-based interaction between the supply behavior of farmers, the demand behavior of consumers and the trade flows connecting them. Farmers maximize their revenue by optimally allocating labor and equipment to cropping and livestock activities, at exogenously specified land resources, stable capacities and levels of technology, while taking the buying and selling prices in the county as given. Consumers maximize their utility, at given prices, by optimally allocating their expenditures according to a utility function that is quasilinear, i.e. linear with unit coefficient in part of non-food consumption and obeying a linear expenditure system in agricultural commodities and the remainder of non-agricultural consumption, which acts as numeraire.

Trade between regions in China and with the rest of the world is cost minimizing at exogenously given world prices and import and export tariff rates. Through its significant geographic detail, the model can incorporate location-specific information on climate, resources and technology while its equilibrium structure enables it to represent coordination flows among the various agents and describe market clearing at different levels.

A model with such a level of detail in classifications is not designed to represent truly endogenous dynamics, as this would inevitably lead to serious accumulation of prediction errors over time. Therefore, a formulation was opted for that assumes an exogenous value for a wide range of driving variables, and statically solves for the values of the endogenous variables for each year of simulation separately, given the assumed values of the driving variables. Together these exogenous variables define a simulation scenario.

Major driving forces are non-agricultural output growth, population growth, urbanization and interregional migration, international prices, changes in land and water resources and stable capacities, adjustment of food preferences, technical progress and trade liberalization. The important role of these driving forces requires a careful and coherent specification of their future trends.

The present report focuses on the findings from five simulation exercises with the general equilibrium model over the period 1997-2030: (i) baseline, (ii) trade liberalization, (iii) rapid economic growth, (iv) high agricultural R&D investment, and (v) enhanced irrigation efforts. Each scenario is designed to reflect different pathways for the major driving forces. The partial model was operated in the background to analyze spatial aspects in greater detail.

The report proceeds as follows. Section 2 highlights the key concerns for agricultural development to be addressed in the report. Section 3 gives a bird's eye view of the model specification expanding on the description given above. Section 4 introduces the scenarios based on the main driving forces that will impact upon Chinese agriculture until 2030. Section 5 reports on the model results for the baseline scenario assumptions, whereas section 6 discusses the outcomes of the other scenarios. Finally, section 7 summarizes the findings, mentioning possible policy implications and concludes with some suggestions for future research. Appendix A describes the output specification of crop and livestock activities, as background in understanding the tables with model outcomes, and Appendix B presents comprehensive tables with outcomes of all five scenarios.

2. Agricultural development issues

As argued in the introduction, major determinants in shaping the future dynamics of China's food and agricultural sector include: (i) increasing non-farm incomes, (ii) further urbanization, (iii) changing consumer demand patterns as a consequence of (i) and (ii) as well as of globalization, (iv) land scarcity due to substantial conversion of land for non-agricultural as well as ecological reasons, and water scarcity, and (v) environmental threats such as ground and surface water pollution that could severely affect drinking water quality in some regions. Here, we will provide some background to each of these determinants, culminating in the formulation of key questions to be analyzed with the model simulations.

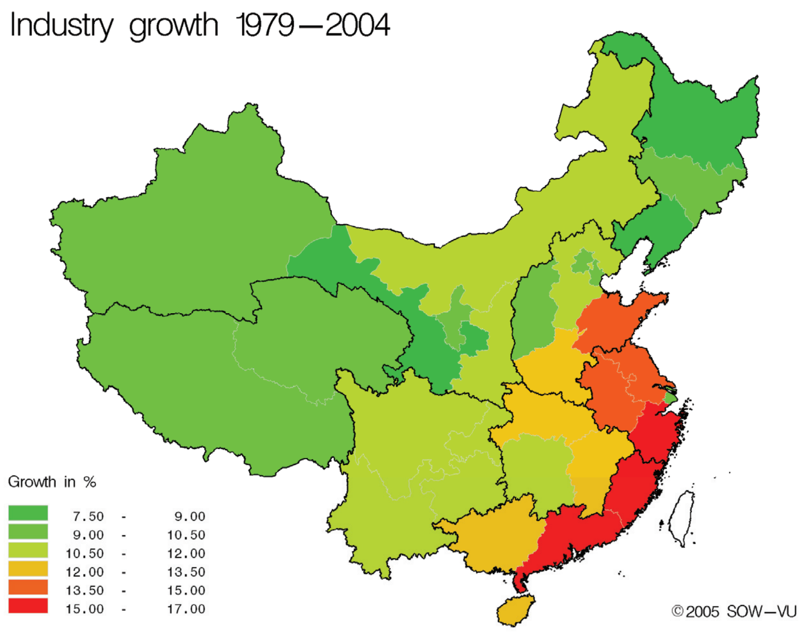
Non-farm incomes
On average, gross domestic product (GDP) has grown at more than 9 per cent annually since the start of the reform program in 1978, an unprecedented record that is even more impressive in view of the nation's size. In 2005, per capita GDP reached 14,000 Yuan or 1,710 US dollar, measured at the official exchange rate. Although the reforms started in agriculture, this sector's growth rate was soon surpassed by the growth rates in industry and services, leading to sharp structural changes in the economy. While agriculture accounted for 40% of GDP prior to the economic reforms in 1970, its share had fallen to 28% in 1985 and further to 16% in 2000. During the same period, the share of industry, including construction, increased from 46% in 1970 to 51% in 2000, and the share of the service sectors from 13% to 33% (Huang et al., 2003). In recent years the relative decline of the agricultural sector continued, reaching a share of 13% in 2005 (NBSCa, 2006).

At its early stage, the reform process outside agriculture could easily make use of local labor surpluses, abundantly available and well-disciplined that made it possible to achieve the initial high growth rates, which in nominal terms were actually quite modest in those days. Far more remarkable is that the high growth rates could be maintained over such a long period. Common explanations[2] comprise the political and social stability, in part attributable to the improved rural and urban living conditions and the success in agriculture, the programs to improve education and accelerate technological progress, and the timely relaxation of migration and trade policies. These factors also made the country attractive to foreign investors, who increased their direct investments from 1.7 billion US $ in 1985 (0.5% of GDP) to 35.8 billion US $ in 1995 (4.9% of GDP) and 54.9 billion US $ in 2004 (2.8% of GDP). More importantly, the astonishingly high domestic saving rate of around 40 per cent of GDP in most years (NBSCa, various issues) made it possible to finance massively the investments that fueled this growth.

Figure 2.1 gives an illustration of the geographical distribution of these developments, expressed as the average annual provincial growth rates in the industrial sector (including construction) during the period 1979-2004. The figure shows that over the whole post-reform period, growth rates were highest in the Southern and Eastern coastal areas, reaching more than 15% annually, but also in inland areas average growth was impressive, largely due to the success of Township and Village Enterprises (TVE's) in absorbing rural labor from the own region. In all provinces the average growth rates reach above 7.5% and in most inland provinces even above 10%. For services, the differences across provinces were even less, with all growth rates ranging from 10% to 14% annually. Hence, per capita non-agricultural incomes have risen significantly in every province.

[2] E.g. Arayama and Miyoshi (2004), Huang et al. (1999), Hubacek and Sun (2001) and Keng (2004).

Figure 2.1 Growth rates of industry (including construction) by province, 1979-2004



Source: calculated from NBSC, Statistical Yearbook of China, various issues.

However, under fast economic expansion seemingly small differences in regional performance can eventually create significant disparity. Over a period of 25 years the difference between, for instance, 9 and 12% annual growth leads to 100% difference in the cumulative factor of increase (8.6 versus 17). Migration from the slower to the faster growing segments of the economy could not mitigate these gaps, especially not in the earlier, restrictive years of the reform period, and neither could growth in agricultural incomes. Therefore, the rapid non-agricultural expansion was a source of increasing inequality across regions, which is confirmed by the income data in Table 2.1, taken from Lin et al. (2004).

Table 2.1 Regional income disparity, 1985-2000

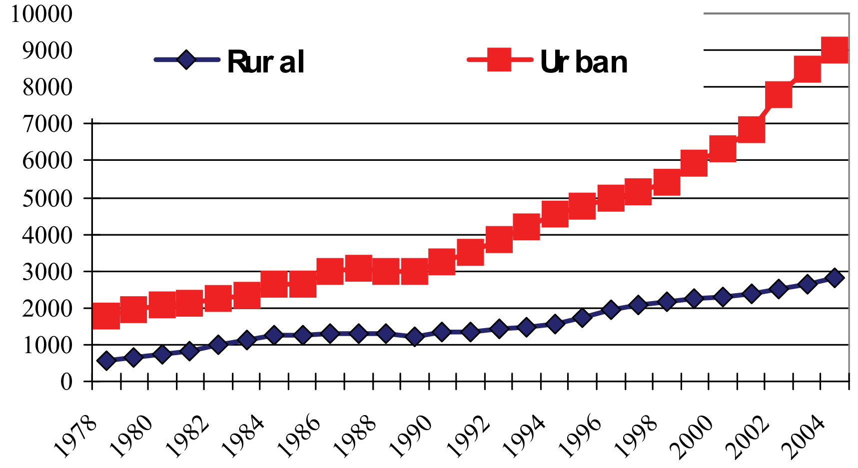
	1985	1990	1995	2000
Coast-inland income ratio				
Urban	1.25	1.31	1.42	1.42
Rural	1.27	1.38	1.66	1.67
Urban plus rural	1.31	1.43	1.65	1.65

Source: Lin et al. (2004). Coastal provinces are Liaoning, Hebei, Tianjin, Beijing, Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi and Hainan.

Table 2.1 shows that the relative incomes (corrected for provincial differences in inflation) of coastal provinces increased steadily from 1985 to 1995 and then stabilized more or less in the last years of the previous century. The differences are larger for rural than for urban areas, signaling that in coastal provinces the rural areas benefited more from the non-agricultural expansion than in inland provinces.

In addition, the fast expansion outside agriculture led to widening income disparities also within the same province, especially between urban and rural areas. The national average per capita rural and urban incomes in the period 1978-2004 are shown in Figure 2.2, expressed in constant 2000 Yuan. The absolute income gap increased in all years since 1985 but the relative income gap, albeit less easy to see in the figure, shows an alternating picture, with its lowest value in the mid-eighties at about 2.5, then rising until 1995, declining slightly between 1995 and 2000 and rising again in recent years, reaching a value of around 3.3 in 2004.

Figure 2.2 Development of rural and urban per capita income (in constant 2000 Yuan)



Source: calculated from NBSC, Statistical Yearbook of China, various issues

The rising inequality across and within regions is also reflected in the trend of the Gini coefficients, which for rural areas went up from 0.24 in 1980 to 0.37 in 2003 (NBSCc, various issues). 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 industrial growth rates between the developed and less developed regions shrank significantly since the mid-1990s (Huang *et al*. 2003, Table 9). Nonetheless, since the annual rate of net inter-regional migration is typically less than 1 percentage point (Liu *et al*. 2003, Table 11), these differences in growth rates still generate a widening income gap on a per capita basis.

The consequences of continued growth outside agriculture would be threefold: (1) there will be strong competition for land and water in urban and semi-urban areas, and in some regions possibly also for labor, (2) food self-sufficiency becomes less critical as the country can afford significant agricultural imports, (3) the rising incomes will shift demand to better quality foods. These three developments combined define the major policy challenge of containing the widening income gap between the agricultural sector and the rest of the economy, and more generally between urban and rural areas.

Population dynamics

When the People's Republic was founded in 1949, it counted a population of 540 million people. Two decades later the figure had risen to more than 800 million and in 2005 it reached 1.3 billion. Despite these enormous increases in absolute numbers, the actual growth rates have been rather moderate, with an average annual rise of 2.0% from 1949 to 1970 and only 1.4% since 1970. Indeed, population policies and campaigns have been ongoing ever since the 1950s. During the 1970s, a campaign of 'one is good, two is acceptable and three is too many' was conducted, and in 1979 the emphasis was even more drastically placed on the benefits for the country of having only one child per household, promoted by a system of social control and fines. Therefore, in view of the medium term effects it is no surprise that natural population growth has by now dropped further to 0.6 per cent annually.

At present, the Chinese population is still young with 36% below the age of 25, and a fraction of working age population of 72% (NBSCa, 2005, Table 4-6). This composition has created a vigorous and mobile labor force that fuels current growth and supports high levels of savings. Furthermore, the youthfulness of the population will inevitably keep population numbers rising for many years to come, despite low fertility rates. Specifically, the present demographic situation exhibits two counteracting trends: while economic growth, urbanization and the associated change in lifestyle may lead to lower fertility rates, modernization and the opening of society might trigger a reversal of the strict one-child policy in family planning. The latter could also reverse the recent unfortunate trend of increasing male surpluses in the lower age classes, as becoming more and more visible in the regular population figures, with 55% male among all children below the age of ten.

Apart from the age composition, the concentration of its 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, and the vast dry grasslands of the north-central region remain virtually uninhabited. About 1.15 billion people, or about 90 percent of the population, live on little more than 30 percent of China's land area. This agrees with historical settlement patterns, with population 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.

Given the large pool of underemployed rural labor force and the important disparities in income and living standards, the natural push towards rural-urban migration has been strong for a long time. As the absorption capacity of the cities was limited, migration was kept in check through dedicated institutional arrangements such as the *hukou* registration system, the land tenure system and the social welfare and security system, all designed to keep the people linked to their place of origin. Nevertheless, under the pressure of the increasing regional and rural-urban discrepancies the hukou system has gradually been relaxed in the 1980s and 1990s (Liu et al., 2003). During that period, migration from Western and Central China to the Eastern regions, especially the coastal areas, has contributed significantly to the population growth of these regions. The three major destinations were the provinces Shanghai, Beijing and Guangdong, with 3.5, 2.7 and 11.4 million immigrants, respectively, during the period 1990-2000 (Liu et al., 2003). Yet, because of higher fertility the overall population growth rates have not been much lower in the poorer hinterland in the West than in the richer coastal regions since its fertility rates are higher. These regional differences in fertility rate are expected to be maintained in coming years (Jiang and Zhang, 1998).

In spite of its persistent urbanization, China can still be considered a predominantly rural society. In 2000, after two decades of rapid growth outside agriculture with high demand for urban labor, only some 36 per cent of the population was living in urban areas.[3] This distribution could become an impediment to growth, as it creates the problem known as “san nong” (or “three nong”): stagnation of agriculture, farmers’ incomes and rural development. It is appreciated that the agricultural sector cannot resolve these problems by itself, as it needs labor outmigration to improve its productivity per hectare and its income per worker. The authorities recognize this hurdle and have proclaimed the promotion of urbanization as a strategic priority of China’s economic development in the coming decades. In line with this policy, a further relaxation of the hukou system was applied at the beginning of 2001 (Liu et al., 2003) allowing the urbanization rate to rise to over 40 per cent in 2005.

Food patterns

Traditionally, grains have been of overriding importance in Chinese diets, while meat, fishery products, vegetables, and fruits were considered rare luxuries. Obviously, the rising living standards have dramatically changed this picture. Nowadays, urban residents typically prefer a more diverse diet with a greater share of processed foods. All Chinese now eat more meat and dairy products, while grain consumption has levelled off and even declined in some regions. Table 2.2 shows the considerable increases in meat, milk and egg consumption between 1980 and 2000, when per capita consumption of pork more than doubled whereas per capita consumption of poultry meat even became six times as high, in both rural and urban areas. Furthermore, the table shows that per capita consumption of livestock products is still much lower in rural than in urban areas, and that urban consumption is now beginning to diversify towards ruminant meat and dairy.

Table 2.2 Per capita consumption of livestock products

	Rural (kg/person/year)			Urban (kg/person/year)		
	1980	1990	2000	1980	1990	2000
Pork	9.9	14.9	22.1	14.5	29.9	32.8
Beef	0.2	0.5	1.0	0.5	2.5	4.8
Mutton	0.4	0.4	1.0	0.8	2.0	2.2
Poultry	0.8	1.6	4.8	2.0	5.0	12.3
Milk	0.6	1.4	1.5	4.6	10.4	18.6
Eggs	1.6	3.9	8.0	5.0	13.7	18.7

Source: CCAP data base. The figures are higher than the official ones due to coverage of consumption outside the own house.

Also within rural and urban areas major differences can be observed. For example, according to the 2006 Statistical Yearbook of NBSC, meat consumption of poorest urban households only reaches 60% of the level of middle income households and even less when food eaten outside home is taken into consideration. By comparison, the Chinagro data base (Van Veen et al., 2005) reveals that in 1997 average per capita meat consumption of the poorest third of the rural

[3] We adopt 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).

population was only half of the consumption of the richest third. This strongly suggests that meat consumption will continue to grow fast in coming decades, given the expected income rise and further urbanization.

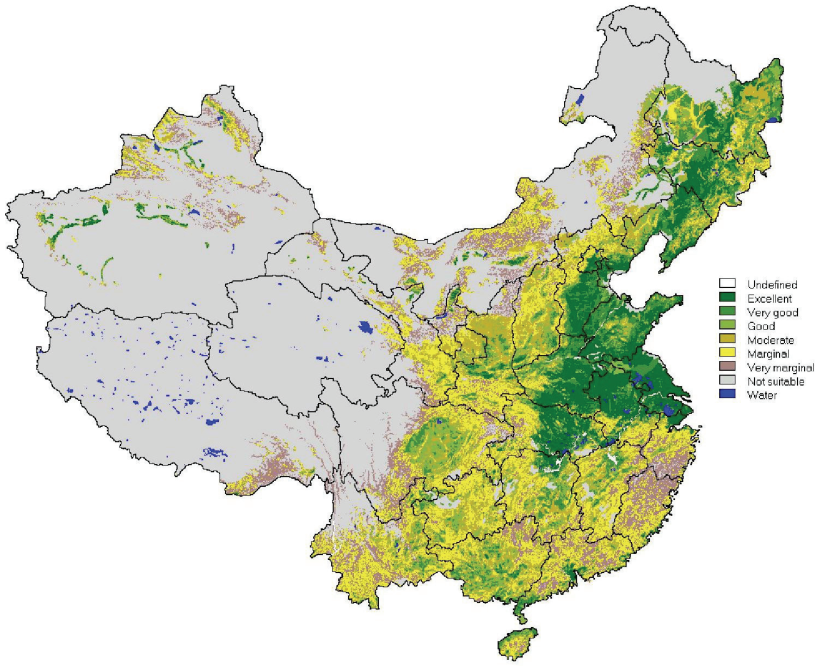
International comparison confirms this conclusion. According to FAO's most recent Food Balance Sheets (FAO, 2007a) China's average food calorie supply per person per day still falls about 15% below the level of rich developed countries, a difference almost fully due to a lower consumption of animal products. Current (i.e. 2003-2005 average) food calorie supply of animal products in China is 609 kcal per person compared to 482 in South Korea, 585 kcal in Japan, 955 in UK, 1063 kcal in USA, 1103 in Germany and 1255 in France. These gaps are expected to disappear in the coming decades due to the surge in meat consumption of the poor segments of the population (see also Keyzer et al., 2005). Furthermore, looking more closely at the figures for the Asian countries, it appears that with 37 kcal against 89 kcal in South Korea and 172 kcal in Japan, today's calorie intake from fish is on the low side in China as compared to these neighbors, suggesting that fish demand might rise quickly as well, presumably leading to intensified aquaculture in China, as ocean fishery would never suffice to fill the gap. Since for all practical purposes aquaculture can be considered a form of intensive livestock production, this only amplifies future feed grains requirements.

Farmland and water resources

Within agriculture itself, availability of arable land is generally perceived as the major determinant of the nation's capacity to produce sufficient food for its huge population. Despite its large territory, China is severely limited in its farmland resources, which are, moreover, threatened by land degradation and by the expansion of non-agricultural land uses in response to rapid economic growth and urbanization, particularly in the river plains. Total cropland area is currently estimated at about 135 million hectare (or 0.1 hectare per inhabitant), of which 10 million hectare consists of orchard land. Figure 2.3 gives a geographical overview of the land suitability for cereal cropping, based on the AEZ agro-edaphic suitability classification and assuming an intermediate level of management and input conditions (Fischer et al, 2002). In Western-Eastern direction, land suitability is highly correlated to the distribution of population but within the coastal regions the population concentrations in North and Northeast are much better endowed with good-quality cereal land than those in the South.

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

Figure 2.3 Land suitability for cereal production



Source: calculated by IIASA following the methodology described in Fischer at al. (2002)

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 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 resulted in 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 brake 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" Program. As the ecosystem services and environmental goods provided by the green lands are not rewarded by the market, government has a crucial role to play in this domain to combat environmental degradation and to act as a trustee for future generations in its natural resource management. 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 the largest areas of fragile marginal lands, the drop in agricultural production potential is mainly caused by construction activities 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 (Lu *et al*, 2004).

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 is supposed to take place. This creates asymmetric incentives and monitoring difficulties. 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 usually located in more remote and backward areas. Third, execution of land reclamation, consolidation or rehabilitation projects is expensive. Finally, even disregarding these costs, farming might not be economically viable on these compensation lands. Not surprisingly, in view of the difficulties, a recent land survey suggests that, on average, compensation takes place for only about two-thirds of newly built-up land converted from farmland and this only as long as reclaimable land is available within the same province (Lu *at al.* 2004). On the whole, in the period 1987-2000, 9.1 million hectares of farmland was lost whereas 5.1 million hectares was reclaimed, leading to the net loss of 4 million hectares mentioned earlier.

Next to the availability of farmland itself, adequacy of water control is the major determinant of agricultural productivity. Nearly 45 per cent of China's farmland (excluding orchards) is irrigated, and because of the common practice of multi-cropping on this land, even 54 per cent of all sown area is irrigated. The share of irrigated land varies significantly across regions, due to diverse environmental conditions, and ranges from 74 per cent in the East Region to 21 per cent in the Northeast. Farming is also more intensive on irrigated land. Under similar natural conditions, cropping on irrigated land uses 50 per cent more farm labor and 100 per cent more chemical fertilizers than cropping on rainfed land, and its yield is generally more than double. We estimate that 72 per cent of grain output is produced on irrigated land. For rice, the share is well over 90 per cent, for wheat over 85 per cent, whereas it only is about 45 per cent for maize and 30 per cent for soybeans, both major feed grains.[4]

In terms of potentials for future expansion of irrigated surfaces, 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. By contrast, in the North region, water availability is a pressing problem due to fast rising non-agricultural water demand. The water resources of mainly the middle and lower reaches of the Yellow River and the Huai and Hai watersheds are severely overexploited (MWR, 2002). The difference between renewable water supply and demand is being made up by groundwater overpumping, lowering the water table in several areas of the North China Plain by 1-2 meters per year and allowing saltwater intrusion in coastal areas. 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. 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. In addition, plans have been designed and work has begun for the South-to-North Water Transfer Project consisting of three large diversions to bring nearly 45 billion cubic meters of water per year from the Yangtze River to the dryer areas in the North, to be constructed phase by phase and to be completed in 2050.[5]

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[4] The figures in this paragraph are from the Chinagro data base. The definitions of the regions of the Chinagro model are shown in Figure 3.1.

[5] To give an impression of the size of these works: MWR (2002) estimates total national water use in 2002 at 550 billion cubic meters!

Agricultural adaptation and environmental threats

The gradual shift of production responsibility to farm households over the past decades, initiated with the dismantling of the communes and the introduction of the Household Responsibility System in the period 1979-1984,[6] has enabled the agricultural sector to adapt to changing external conditions such as the process of trade liberalization and the increased demand for richer diets. This adjustment led to significant changes in the composition of the sector, from one that was "taking food grains as its key link" (the mantra during China's Socialist period) to a dynamic sector in which livestock and feed grains, aquaculture, high valued fruits and vegetables can increase their share at a breathtaking pace. The agricultural sector in this new, commercialized, market-oriented setting is altogether different from the one that existed even a decade or two ago that primarily aimed at producing enough rice and wheat to supply the people with sufficient calories. Table 2.3 shows the relative decline of the foodgrain areas and the relative increase of vegetables, fruits and feedgrain areas since 1985, as well as the rising share of the livestock sector in farm valued added.

Table 2.3 Changes in agriculture, 1985-2005

	1985	1995	2005
Total sown area, in million ha	143.6	149.9	155.5
of which:			
Rice, in %	22.3	20.5	18.6
Wheat, in %	20.3	19.3	14.7
Maize, in %	12.3	15.2	17.0
Soybean, in %	5.4	5.4	6.1
Tubers, in %	6.0	6.4	6.1
Vegetables, in %	3.3	6.3	11.4
Orchard area, in million ha	2.7	8.1	10.0
Share of livestock in agricultural output value (in %)	22.1	29.7	33.7

Source: NBSC, 2006 Statistical yearbook.

Following the strong improvements in yields per hectare, domestic foodgrain availability has not really suffered from the area decline. The Statistical Yearbooks (NBSCa, various issues) show that wheat yields went up from 3.0 ton per hectare (average 1985-1987) to 4.2 ton per hectare (average 2003-2005), while paddy yields increased in the same period from 5.3 to 6.2 ton per hectare and maize yields from 3.8 to 5.1 ton per hectare. Therefore, moderate food grain imports have sufficed so far. In the period 1995-2004 annual net wheat imports averaged 2.4 million tons (say, 3% of production) whereas for rice there were, on average, even net exports of 1.3 million tons per year. Yet, due to fluctuations across years foodgrain supply did remain an issue of major concern for policy makers, leading to frequent alterations of grain procurement policies, also in the last decade.[7] In the end, the advocates of compulsory grain procurement policies seem to have lost their case, especially after the huge costs of stock disposal incurred in 2000-2004, as the

[6] Under the Household Responsibility System farmers obtained individual land tenure rights, initially for a period of 15 years. For a discussion of the agricultural reform experience see e.g. Huang and Rozelle (2004).

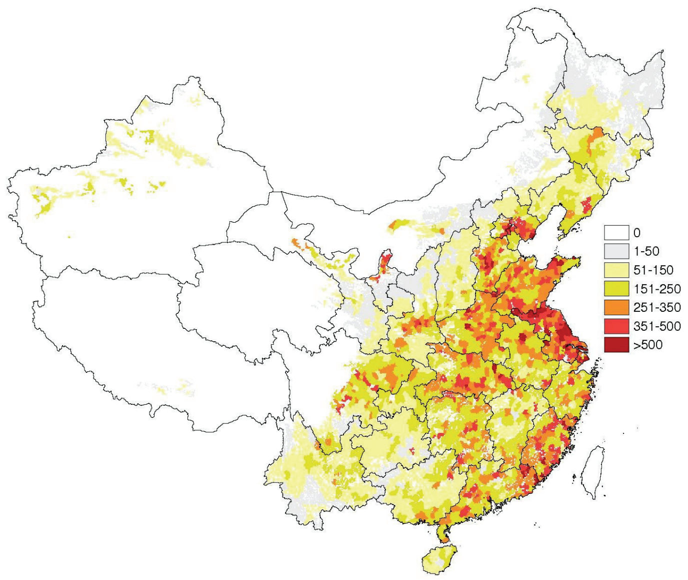
[7] Overviews of China's grain policies since the initiation of the agricultural reforms in the late 1970s are provided by e.g. Huang and Rozelle (2004), Gale et al. (2005) and Chen (2007, chapter 2).

procurement system was abolished and replaced by a more market-oriented national grain reserve system.

The rise in per hectare yields, observed for grains as well as for other crops, went along with considerable shifts in input use. In the period 1985–2005 the availability of machinery power increased with 6.1% annually, and chemical fertilizer use with 5.1%. Furthermore, the share of irrigated land increased with 1.1%. But this was also a period of diminishing labor use. Between 1985 and 1999, manpower input per hectare went down with 2.6, 2.3 and 1.7% annually for rice, wheat and maize, respectively, according to the China Agricultural Production Cost and Revenue Compilation (NDRCa, various issues). These reductions are seen as the combined effect of technological improvement and a more rational use of labor induced by better employment opportunities outside agriculture.

Yet, these productivity increases leave much room for further improvements. For example, while grain yields on average achieve higher levels than in most developing countries, they lie still well below the average levels in developed countries: the 2003-2005 average yields for wheat were 4.2 ton per hectare against 7-8 ton in Western Europe, for paddy 6.2 ton per hectare against 7.6 ton in USA and for maize 5.1 ton per hectare against 8-9 ton in Western Europe and even more than 9 ton in USA (FAO, 2007c). Also within China, comparison of realized yields with yields achieved at experimental stations points to significant room for improvement (Jin et al., 2002).[8] These gains could be achieved through wider adoption of improved HYV seeds, a more balanced application of chemical fertilizer 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, increased irrigation efficiency, and more generally, through improved extension services and related agricultural research.

Figure 2.4 Hot-spots of fertilizer consumption (kg nitrogen/ha cultivated land), 2000



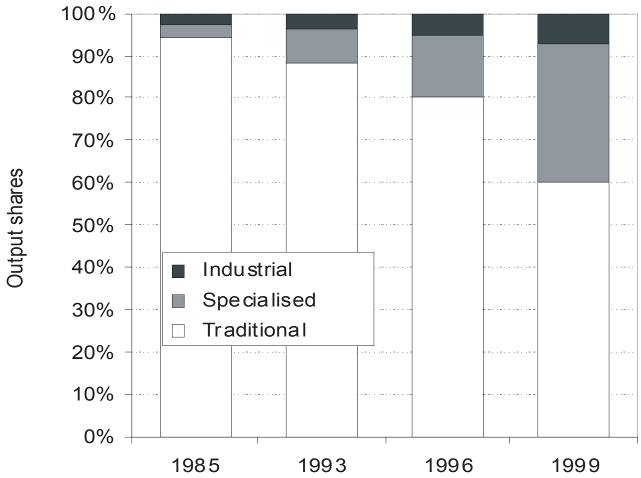
Source: IIASA calculations described in Ermolieva et al. (2005)

[8] For the year 1995 this source mentions 7.2, 5.2 and 7.9 ton per hectare as adopted potentials for paddy, wheat and maize, respectively. These levels have risen since.

In raising future crop yields, special attention will have to be paid to the application of fertilizer, from both chemical and organic origin. Application of chemical fertilizers has now reached high levels, on average close to 350 kg nutrient per hectare. Continuation of this increasing trend would pose severe threats to ground and surface water quality, in the area of application as well as at more distant locations (non-point source pollution). Figure 2.4 shows the hot-spots of fertilizer consumption (chemical plus organic) in terms of kg nitrogen per hectare cultivated land, as determined for the year 2000.

With respect to livestock, 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 with 5 to 1000 pigs per unit and large-scale, industrialized farms with more than 1000 pigs per enterprise. To satisfy the growing meat demand, China has, as many other countries, rapidly adopted intensified peri-urban and urban livestock production systems. As shown in Figure 2.5, the share of the traditional backyard systems in pork production decreased sharply from 95% in 1985 to about 60% in 1999. Given the foreseeable rise in demand for meat and the limited potential of the traditional, crop residue- and pasture-based production technologies, this trend will definitely persist.

Figure 2.5 Share of pork output by production system, 1985-1999

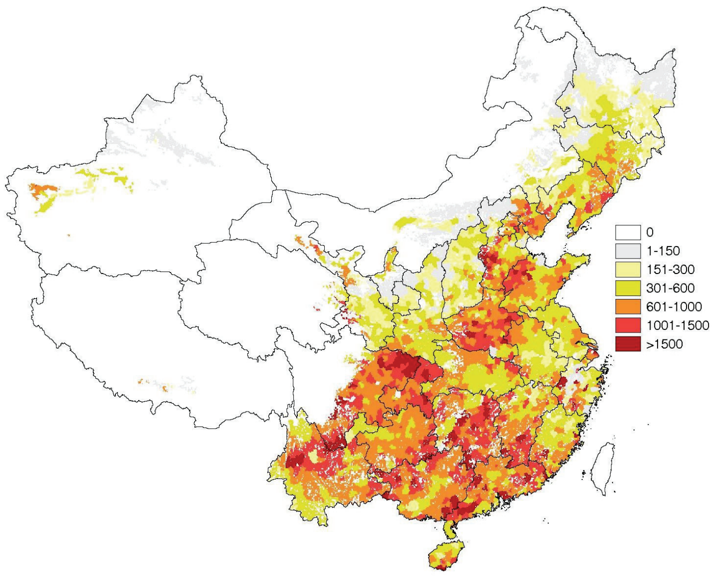


Source: Somwaru et al., 2003.

The rapid adoption of intensified livestock production systems has far-reaching geographical, economic and social implications, as these systems tend to be introduced in areas where feed can be obtained at low cost and where market outlets are favorable. Hence, they concentrate in the vicinity of large cities and harbors, close to consumers, with easy access to foreign markets and where food and feed processing industries produce large volumes of byproducts 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.

In this connection, some important geographical aspects of the country need to be noted. Several major urban agglomerations are situated along the coast and, except in the delta region, separated from the hinterland by hill tracts. Since inland transport is far 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 feedgrains from New York or Rotterdam to Shanghai than from the Red Basin, where much of the livestock is being produced, and similarly, transporting maize from the Northeast to the Southwest may be as costly as importing it from overseas. This argument limits the possibilities of inland farmers but it works also the other direction: farmers located inland have a considerable advantage in supplying nearby inland population concentrations with fresh products as compared to foreign traders, the more so since richer consumers prefer fresh meat that is not deep-frozen and hence produced locally, with little competition from far-away coastal areas. Figure 2.6 illustrates this by showing the hot-spots of high intensity of confined (i.e. non-pastoral) livestock for the year 2000.

Figure 2.6 Hot-spots of confined livestock (livestock biomass in kg/ha cultivated land), 2000



Source: IIASA calculations described in Ermolieva et al. (2005)

Currently, close to 50% of all feed still originates from crop residuals, grass and household waste, mainly used in traditional livestock systems. Because of their bulky nature, these feeds are not transported over large distances and hence referred to as local feeds. Although availability of grass and crop residuals will increase further due to improved cultivation techniques, and special green fodder crops will play an increasing role as well, local feeds cannot satisfy the needs of the fast growing intensified livestock sectors that will, therefore, require rising amounts of tradable feeds. Figure 2.6 gives an indication of the areas where strongest increases in feed use are expected. It appears that these areas are mostly limited in their scope for expanding feed production, particularly in South, leading to the question whether it will be more profitable to get the feed from the grain surplus areas in the North and Northeast or to import them from abroad. So far, the share of imports in national feed supply is rather limited. In terms of energy content, imports total around 10% of tradable feed intake,[9] a share that would even be much lower had we applied a correction for the (subsidized) maize exports realized since 1997 to get rid of excessive domestic stock levels.

The geographical concentration of confined livestock leads to three types of environmental concerns: (1) nutrient burden where not enough land is available for manure disposal and

[9] Calculated for 2003 from the Chinagro data base.

recycling, causing land and water pollution, (2) danger of rapid spread of contagious animal diseases, and (3) road congestion and pollution caused by the trucks that transport the required amounts of feed. Together with the above-mentioned problems of nutrient losses in areas with high chemical fertilizer application, as well as with the food safety regulations that may restrict the use of pesticides and the choice of food processing techniques, these concerns define the environmental constraints within which China's agricultural sector will have to adapt further to the changing external conditions. Even relocation of intensified livestock farms possibly has to be considered, taking into account the danger of contagious animal diseases together with the relative costs of transportation of animals (or meat) compared to the costs of transportation of feed.

Key questions
The considerations above lead to the following key questions for further analysis through scenario simulations with the model:

1. Will the increasing demand for meat under continued growth and rural to urban migration cause China to become a major importer of either meat or feed grains or both?
2. Will the shift to luxury food, jointly with technological progress, generate a grain surplus 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?
3. Will farmers in poorer regions of China be able to increase their incomes by supplying the growing domestic livestock and feed grain market, or will intensive large-scale production units and foreign exporters be better placed particularly for deliveries to the coastal regions?
4. How can the regions in Northeastern China that still have large potential for feed grain production, overcome the disadvantage of their long distance from the livestock industry?
5. How can the irrigation requirements in the semi-arid and generally water-deficit areas of the North China Plain be met to turn them into major feed producing zones?
6. What are appropriate agricultural development options in Southern provinces that are less suited for livestock and cereal production but enjoy ample rainfall?
7. How will enhanced trade liberalization measures affect specific commodities with strong competition from outside, such as sugar, protein feeds and feed grains? How will this impact on the income distribution across regions and between the rural and urban segments of the population?
8. To which extent are the projected developments in livestock intensities and irrigation requirements environmentally sustainable in the longer term, and if not, what type of measures should be taken to achieve sustainability?

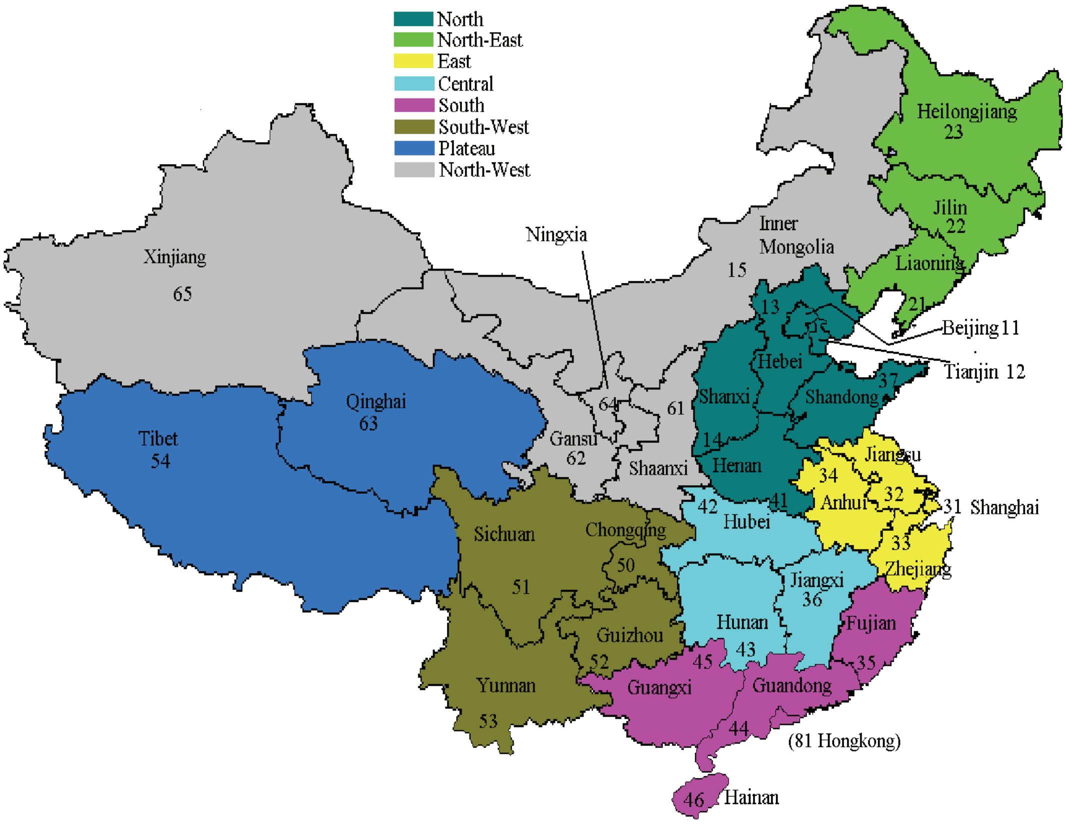
As mentioned before, the Chinagro-project seeks to address these questions by means of a dynamic simulation model as a device to project the developments under different assumed scenarios with respect to policy assumptions as well as the external environment in which the sector will operate. These scenarios establish plausible future trends for all important socioeconomic, political, and environmental processes that are and have to be treated as given in the simulation model. Before proceeding with the description of the scenarios, we give a short overview of the Chinagro general equilibrium welfare model as used for scenario simulations.

3. A bird's eye view of the model

The general equilibrium welfare model (Keyzer and Van Veen, 2005) used for scenario simulations is cast in the form of a single-period welfare program that is solved for selected years of simulation over the period 1997-2030, evaluating solutions under given scenario conditions with respect to resource availability, demography, non-agricultural growth, life-style changes, technological progress, international prices and government policies. The years selected for simulation are 1997, 2003, 2010, 2020 and 2030. With respect to validation, the model fully replicates for every county and region of China in the 1997 base-year conditions, adequately mimics changes over the period 1997-2003 and provides interpretable results until 2030.

As mentioned in the introduction, the welfare model is an 8-region model, with farm supply described at the much more disaggregated county level. The regions are shown in Figure 3.1. The distinction between the eight regions is based on their respective geographic, agro-climatic and demographic features, and economic development levels. The regions are subdivided into provinces, the actual administrative units in China.

Figure 3.1 Map of China with provincial boundaries and the eight Chinagro regions



Note: Taiwan is not included in this analysis and, therefore, absent from the map.

Farm supply is modeled for each of 2433 counties, covering virtually the whole of China, with farm output cast in terms of 28 activities consisting of 14 types of crops, 9 types of animals and 5 related activities such as collection of household waste and supply of machinery power. Crop activities take place on three land use types (irrigated land, rainfed land, orchards), whereas the livestock activities are conducted in six different livestock systems, distinguished on the basis of mode and intensity of production. The output of the cropping land use types and livestock systems comprises both local and tradable commodities. Local commodities are traded only inside the own county, and even then only over limited distances. They consist of local feed (grass, crop residuals, household waste, green fodder), organic fertilizer (animal manure, nightsoil) and power (draught power, machinery power). Tradable commodities are exchanged across all regions and from and to abroad. Their prices are determined endogenously in the general equilibrium model. The model distinguishes 17 of such tradable commodities. Appendix A presents the supply classifications and explains the relation between agricultural activities and tradable commodities, for livestock production separately by livestock system.

As usual in general equilibrium (see e.g. Ginsburgh and Keyzer, 2002), supply and demand are balanced for all commodities simultaneously through domestic (here, intra-regional and inter-regional) and international trade, jointly with price adjustment subject to various policy interventions such as tariffs and quotas on international trade. The model has been implemented as 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, mainly in GAMS (see Brooke et al., 1998) but with use of dedicated Fortran and SAS programs for production of tables and maps.

In tandem with the general equilibrium welfare model, commodity-specific models have been developed that follow a common specification as a partial equilibrium model with transportation costs. These partial equilibrium models are spatially explicit and represent supply, demand and trade flows on a 10-by-10 kilometer grid, totally about 94,000 cells. They serve to 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 taxes and subsidies. This in particular makes it possible to calculate the density distribution of consumer as well as producer prices within every county and to infer average transport margins from price information, for subsequent use in the general equilibrium welfare model.

The general equilibrium welfare model itself focuses on the description of (a) supply response by farmers under their prevailing technology and natural resource endowments by county, (b) the behavior of consumers by region and income group for rural and urban separately, (c) the balancing on the regional markets of supply and demand, with appropriate trade between regions and with the foreign markets. Together, these decisions of producers, consumers and traders are such that at given exogenous conditions (in particular, agricultural resources and technology, non-agricultural output, international prices, government policies and the country's trade surplus) and at given welfare weights, optimal social welfare is obtained. Indeed, 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.

The (unique) equilibrium is found at regional prices for which the net quantities purchased in every region coincide with the net deliveries by traders. Of the 17 traded commodities mentioned earlier, 13 are food commodities and 2 are feed commodities whereas 1 commodity (maize) is used for both food and feed and 1 commodity is non-agricultural. The price of the non-agricultural commodity is kept equal to the given export f.o.b. price for all market locations considered (after conversion from the dollar to Yuan). Hence, taxes and trade and transportation costs on non-agriculture are not distinguished separately. Since the utility functions of consumers and the public demand by government treat the non-agricultural good as residual (i.e. are linear in it with unit coefficient), and the non-agricultural export f.o.b. price and the dollar-to-Yuan conversion rate are kept constant over the years, the domestic non-agricultural price remains fixed and normalizes all other prices, as is necessary for this commodity to act as numeraire. Therefore, all resulting prices and expenditures can be interpreted as "real" and comparable to the 1997 price and expenditure levels.

The specification of the model is best understood in terms of the behavior of the individual agents that appear in it, i.e. consumers, farmers and traders:

Consumers

Consumers are distinguished by location (urban, rural), by region and by income group (poor, middle, rich). Each individual of a specific group spends revenue on food according to a linear expenditure system with time-dependent coefficients. As mentioned earlier, expenditures on non-food appear in this demand system as well but also separately, as closing item on individual budgets of consumer groups and in the national government budget. Revenue originates from direct earnings (entrepreneurial income, factor rewards) and private transfers as well as from government transfers (which are negative in case they pay income tax). Welfare weights on group utility determine the level of uncommitted expenditures of each consumer group. Hence, consumer demand adjusts both to scenario variables and to variables determined by the model itself, the latter of which are referred to as endogenous variables.

The scenario variables include (a) the population numbers in every group as resulting from natural fertility, mortality, 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 on the group; (d) the price of non-agricultural commodities. The "only" endogenous variables are the prices of all agricultural commodities, at consumer level, that is after the appropriate processing from raw material to retail level.

Farmers

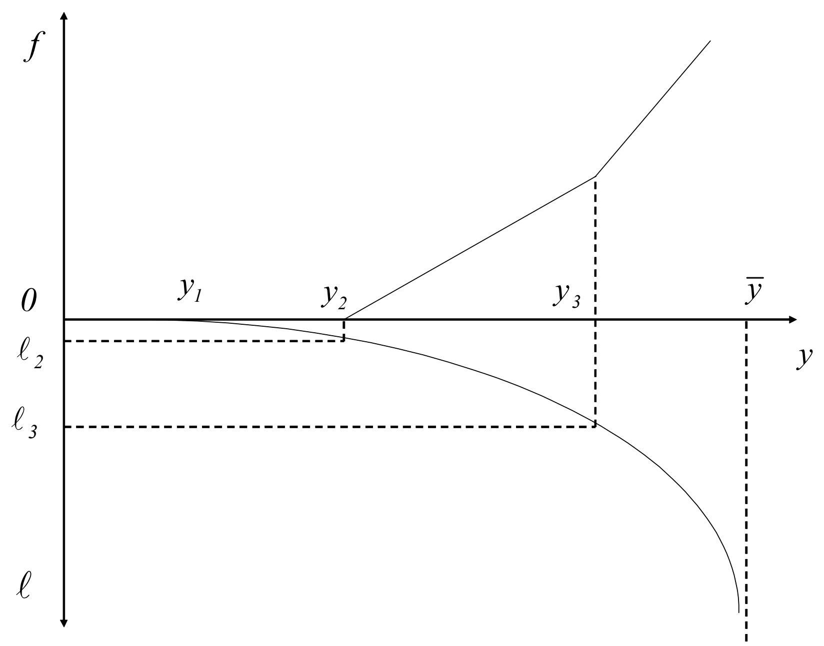
Farms are distinguished by county. The typical farm of a county chooses its cropping pattern and livestock activities by allocating its labor and equipment so as to maximize its current revenue, i.e. the net proceeds from sales minus the cost of current inputs (purchased feeds for animals and fertilizer for crops), subject to technological constraints specified separately for cropping land use types (irrigated land, non-irrigated land, orchards) and for several types of livestock systems (ruminant, non-ruminant with varying degree of intensification), for given land areas and stable capacities.

The technology of each land use type (including the livestock systems) is represented via a two-branch production function,[10] as shown in Figure 3.2. The upper panel indicates how much fertilizer per hectare f (respectively, feed per stable unit) 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 labor per hectare (respectively, labor per stable unit). The yield appears on the horizontal yield-axis, the level y_1 refers to the yield obtained without any input of purchased fertilizer and formal labor and bullock or tractor power and equipment (i.e. with only child labor or informal work), y_2 to the yield obtained with formal labor ℓ_2 but without purchased fertilizer (resp. purchased feed), i.e. with locally available manure and nightsoil (resp. with locally available crop and household

[10] Earlier experience in estimating production relations for China as described in Albersen et al. (2002), contributed to this specification.

residues), and, finally, y_3 to the yield-threshold beyond which purchased fertilizer (resp. feed) use becomes less effective. The curve in the lower panel shows the response with decreasing returns to labor, where the bio-physical cropping potential $\overline{y}$ appears on the right-hand side as a ceiling (asymptote) and measures the maximal amount of biomass that could be produced through photosynthesis under the given climate and soil conditions. For extensive grazing, a similar relationship is postulated but with the herd size in the role of labor input.

Figure 3.2 Two-branch production function of a typical farm



The variables in Figure 3.2 are indexes, specified at county level by land use type. These indexes, fertilizer (or feed) input f and yield y, in turn determine demand and supply of tradable commodities, whereas labor input ℓ is expressed in terms of equipped labor equivalents, comprising labor as well as available animal draught power and machinery. Local commodities (organic fertilizer and local feeds) are also accounted for and reduce the demand for fertilizer and feed input f by shifting the intercept y_2 .

On the output side, every land use type produces several crop (resp. livestock) commodities, according to substitution possibilities within each land use type.[11] 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 byproduct that can be used as fertilizer, and hence substitutes for purchased fertilizer. Similarly, cropping systems produce various tradable goods such as grains, vegetables, fruits and marketed feeds, as well as crop residuals such as straw and husks that can be used as local source of feed for livestock. Clearly, ruminants can use feed from pastures and grazings as well as other types of

[11] The calculation proceeds for each land use type in two steps, one describing substitution between livestock and cropping activities, the other associating a commodity basket to each activity. The correspondence is given in Appendix A.

roughage, while non-ruminants are more restricted in their diet. Exogenous, county-specific utilization rates account for the limited possibility to use all byproducts from farming.

Hence, the supply model has as trend scenario variables (a) the area of rain fed land, irrigated land, orchard land, grazing land, forests, built-on land; (b) the stable capacities of the various livestock systems; (c) the total farm labor available equipped with animal and tractor power; (d) utilization rates of local feed and organic manure. Furthermore, (e) neutral technological progress enters by specified trends on the aggregate yield of a land-use type, and (f) labor-saving technical progress by specified trends on the labor-effectiveness in a land-use type. Most importantly, the prices at county level endogenously determined on the market enter as determinants of farm supply and input demand.

Traders

Traders minimize for every traded commodity the total cost of delivery they must 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 as well as the unit cost to process the agricultural product from county level up to consumer level. This leads to trade levels as well as regional and county prices at which deliveries take place. For this trade module, (a) government taxes, tariffs and quotas are the scenario parameters describing the policy being implemented. Furthermore, (b) the foreign trade prices and (c) the trend assumptions on the unit cost of trade, transport and processing enter as scenario variables.

Non-agriculture

Non-agricultural supply and demand is specified by region (hence, not at county level) and largely exogenously, thus setting the framework within which the agricultural sector operates. The non-agricultural scenario variables include (a) output volumes, (b) public consumption, (c) investment demand and (d) changes in inventories, whereas (e) technical changes may be implemented via trends in the input-output coefficients. Also output from fishery and forestry are represented exogenously. Given the dominant role of non-agriculture in China's foreign trade, the country's trade surplus (also a scenario variable) is determined in harmony with these non-agricultural trends.

Methodological results

In the process of building the Chinagro general equilibrium model, the following methodological results could be obtained (see Keyzer and Van Veen, 2005, for further details).

First, we could prove that the model possesses a solution that is, moreover, unique, and maximizes social welfare once all distortions are eliminated.

Second, we have specified a modular calibration procedure through which it can be assured that the base year (1997) equilibrium solution of the full welfare program exactly replicates the base-year data. Agricultural supply is calibrated, in a modular way as well, for every county so that production as well as factor and non-factor input use are fully replicated and maximize county revenue. For interregional trade, we apply 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 stock changes 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 very large model, as it makes it possible to keep database operations fully separate from the modeling work, while improvements in the database are in a transparent way transmitted to the model outcome and future replacements in specific model components can be implemented without requiring a new calibration full of surprises of the complete model. Moreover, initialization at a fully calibrated base-year solution provides a large number of checks and clues for detecting programming errors in the debugging phase of model building, and also speeds up computation.

Third, we have specified a globally convergent algorithm to solve this very large model. This algorithm decomposes the problem in two components, one an 8-region exchange component that maximizes social welfare of consumers while treating the output and input of the 2,433 counties as given and is solved as a regular medium-sized convex program (via a Minos-solve statement in GAMS), the other 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 loop (implemented through parameter adjustments in GAMS) and to prove global convergence. The algorithm proves to be remarkably fast and precise.[12]

[12] Numerical performance is as follows. Starting from given data files and estimates of the consumer demand system, the model calibration and preparation of GAMS-input files for simulation take about 5 minutes, on a regular laptop (Pentium®, 4-M CPU, 512MB RAM, 1.70 Ghz). A five-period simulation (1997, 2003, 2010, 2020, 2030) with tabulation is completed within 25 minutes, at a precision of .08% for every regional commodity price in every year.

4. Scenario Design

As mentioned earlier, the scenarios establish future trends for the important socio-economic, political, and environmental processes to the extent that these are treated as given in the simulation model. This involves consideration of a range of policies and institutional settings, to frame the changing context within which agriculture operates. We consider the following:

- regional development,
- population growth, urbanization and migration of rural labor,
- world agricultural prices,
- land use change dynamics, including level of protection of farmland and climate change impacts, and water sector development, especially with regard to irrigation practices and inter-basin water transfers,
- stable capacities and their geographical spread,
- farm labor availability and mechanization,
- trends of agricultural technological change, and R&D spending in agriculture,
- institutional features of agricultural markets, including policy interventions in domestic markets and policy decisions about the integration of China's agriculture into the international trade system (WTO and bilateral agreements),
- lifestyle changes affecting consumer preferences.

Apart from world prices, climate change impacts and life-style changes, these trends depend to a large extent on government policies.

In view of China's great socio-economic, geographic and ecological diversity, the above-mentioned forces impact very differently on 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 the external economy.

Scenario simulations with the Chinagro-model cover the period 1997-2030. In consultation with all partners and a large number of experts, 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 Van Veen et al. 2005). Then, a process of intensive testing and readjusting followed to arrive at a plausible and broadly accepted simulation of a reference scenario (BASELINE). Finally, a range of scenarios was specified.

All scenario simulations start from a common assessment of the outcomes in reference year 1997 and the latest year for which data were available, namely 2003. Policy variants are evaluated from there onward, for the years 2010, 2020, and 2030 as variants to the baseline. As a first set of simulation experiments, to provide substantive inputs to the Chinagro policy exercises, four policy variants to the baseline are simulated. These policy variants address four key concerns of agricultural development:

- full liberalization (LIBERAL) scenario: assumes gradual removal of agricultural border protection beyond currently planned levels, to be completed between 2010 and 2020,

- high economic growth (HIGHGROW) scenario: assumes a high economic growth path in the non-agricultural sectors, combined with a faster rural-urban migration and hence a higher urbanization level than the baseline,

- high agricultural R&D investment (TECHPROG) scenario: assumes high (Solow neutral) output increasing technical progress for crops and livestock, as well as high labor saving technical progress in both,

- enhanced irrigation development (IRRIGUP) scenario: assumes same changes of total cultivated land as the baseline, but expanded irrigation development.

We describe the assumptions of the baseline (section 4.1) before turning to the four variants (section 4.2).

4.1 Baseline

The baseline is characterized by: (1) continuation of the current growth rates in non-agriculture, supported by large investments in the manufacturing and service sectors and a considerable outflow of labor from the rural areas; (2) this urban and industrial expansion leads to increased pressure on agricultural land and water availability in densely populated counties; (3) at the same time, the higher incomes from non-agriculture lead to shifts in consumption patterns towards more meat and dairy; (4) to cope with possible threats for domestic food supply, government continues its policy of liberalization of agricultural foreign trade, reduces producer taxes and stimulates technical progress by sustained spending on research and development; finally, (5) the international agricultural price projections in the baseline show moderate changes, with increases for feed and meat and a mixed picture for food crops.

Below we discuss these assumptions in more detail, arranged by theme. If geographically different, the trends are presented by region although many of these, such as the trends in population and agricultural resources, are actually specified at provincial level.

4.1.1 Regional development

In the strategy for long-term economic development as laid down in its Tenth and Eleventh Five Year Plans (2001-2005 and 2006-2010), China set ambitious goals to move the nation to a "welfare society" (Xaiokun Shehui) in the next 20 years: (a) doubling of GDP every 10 years, with a smooth transformation of the economy from rural to urban and from agriculture to industry and service based, (b) ensuring sustainable management of the environment, and (c) maintaining a socially balanced growth path (NDRCb, 2006). Doubling of GDP in 10 years means obtaining an annual average growth rate of 7.2%, and, therefore, an even higher rate in industry and services since agriculture cannot grow at such a pace over a prolonged period.

In the period 1997-2003 the industry and service sectors have realized high rates of growth of more than 9% and 8% respectively on average, rather uniformly distributed over the regions (NBSCa, various issues). High growth is likely to continue in the coming decades even though inevitably moving to a lower rate as the size of the economy becomes larger. Huang et al. (2003) have formulated three different growth scenarios about the non-agricultural sector describing the context within which agriculture will operate. Their central projection is used for the baseline and shown in Table 4.1. High growth continues in all regions, but gradually at more common rates, ending with 4-6% in the period 2020-30, implying that by 2020 China's non-agricultural output will have grown to 3.2 times its 2003 level, whereas it will reach 5.3 times its 2003 level by 2030. The table also mentions the growth path for fisheries and forestry (exogenous sectors in the model) that are kept at constant rates of 2.5 and 2%, respectively.

Table 4.1 Non-farm production: regional growth rates in baseline

Region	Sector	1997 output (billion Yuan)	Annual growth rate (in %) at constant prices 1997-2003	2003-2010	2010-2020	2020-2030	**2003-2030**
North	Industry	3248.9	9.8	7.6	5.8	4.6	**5.8**
	Services	1339.9	8.3	9.2	7.6	5.6	**7.3**
Northeast	Industry	1248.7	8.6	6.2	5.1	3.8	**4.9**
	Services	490.7	6.1	7.6	6.2	5.0	**6.1**
East	Industry	3830.0	9.8	8.0	6.2	5.0	**6.2**
	Services	1224.2	9.5	9.6	7.7	5.7	**7.4**
Central	Industry	1255.6	10.5	7.0	5.7	4.0	**5.4**
	Services	506.5	8.7	8.9	7.0	5.2	**6.8**
South	Industry	2385.5	10.5	8.7	6.9	5.7	**6.9**
	Services	949.3	9.5	9.9	8.7	6.6	**8.2**
Southwest	Industry	876.8	7.8	6.0	5.1	3.8	**4.8**
	Services	414.7	8.2	8.6	6.6	5.4	**6.7**
Plateau	Industry	25.1	9.0	7.1	5.7	4.9	**5.7**
	Services	19.5	9.0	8.4	7.1	5.8	**7.0**
Northwest	Industry	530.4	9.5	6.5	5.6	4.3	**5.4**
	Services	300.0	6.7	8.4	7.0	5.8	**6.9**
China	**Fisheries**	**233.2**	**2.5**	**2.5**	**2.5**	**2.5**	**2.5**
	Forestry	**80.4**	**2.0**	**2.0**	**2.0**	**2.0**	**2.0**
	Industry	**13400.9**	**9.7**	**7.6**	**6.0**	**4.8**	**6.0**
	Services	**5244.7**	**8.6**	**9.2**	**7.6**	**5.8**	**7.3**

Promoting balanced development among regions is a separate chapter in the country's Five-Year Plans. This policy is reflected in the distribution of investments and public consumption. Table 4.2 shows for the period 1997-2003 highest growth in investments in the poorest regions, Southwest, Plateau and Northwest. The baseline assumes gradually more moderate increases (as in the output projections above), leading in all regions to investment growth rates of 6.8% and 3.8% for the periods 2010-2020 and 2020-2030, respectively. The growth rate in 2020-2030 might seem rather low compared to the earlier period, but this reflects that it would be difficult to keep on spending productively more than 40% of GDP on fixed investment as is done in the baseline until 2020.

Table 4.2 Exogenous non-agricultural demand: regional growth rates in baseline

Region	Type of demand	1997 level (billion Yuan)	Annual growth rate (in %) at constant prices 1997-2003	2003-2010	2010-2020	2020-2030	**2003-2030**
North	Public cons.	254.1	9.0	12.0	7.0	6.0	**7.9**
	Investment	649.2	11.9	7.4	6.8	3.8	**5.9**
Northeast	Public cons.	97.0	7.7	10.9	7.0	6.0	**7.6**
	Investment	200.5	12.5	7.4	6.8	3.8	**5.9**
East	Public cons.	150.6	11.7	14.2	7.0	6.0	**8.5**
	Investment	650.6	12.7	7.4	6.8	3.8	**5.9**
Central	Public cons.	93.8	7.5	10.7	7.0	6.0	**7.6**
	Investment	228.5	12.0	7.4	6.8	3.8	**5.9**
South	Public cons.	174.3	10.5	13.2	7.0	6.0	**8.2**
	Investment	427.7	13.4	7.4	6.8	3.8	**5.9**
Southwest	Public cons.	83.3	9.5	12.4	7.0	6.0	**8.0**
	Investment	211.3	14.3	7.4	6.8	3.8	**5.9**
Plateau	Public cons.	4.7	17.1	18.8	7.0	6.0	**9.6**
	Investment	12.6	18.3	7.4	6.8	3.8	**5.9**
Northwest	Public cons.	69.2	4.0	7.8	7.0	6.0	**6.8**
	Investment	151.3	16.5	7.4	6.8	3.8	**5.9**
China	**Public cons.**	**927.0**	**9.2**	**12.4**	**7.0**	**6.0**	**8.0**
	Investment	**2531.7**	**13.0**	**7.4**	**6.8**	**3.8**	**5.9**

When comparing non-agricultural output and non-agricultural demand in the period 2003-2030 one may observe that the average growth rate of fixed investments is a little lower than the average growth rate of output, whereas the opposite applies to the average growth rate of public consumption to represent a steady improvement in the provision of public services. Together, these trends point to a gradually more pronounced role of human and institutional capital formation, as compared to fixed capital formation, in maintaining the growth momentum of the economy.

Despite the expected high imports of capital goods associated to the persistently high levels of fixed investment, the trade surplus of the country, also a scenario variable, is assumed to grow at 10% in real terms annually in the period 2003-2030 up to about 470 billion dollar (1997 prices) in 2030, reflecting China's intention to maintain its growth in offshore investments. Combined, the high investment rate and the high trade surplus imply that the domestic saving rate, which is well over 40% in 2003, is to be kept around that level in the baseline.

4.1.2 Population and migration

As discussed in section 2, projections of the regional growth rates of the Chinese population are dominated by three major effects: (1) the large share of young people in the current population, (2) the reaction of the fertility rates, currently rather low as consequence of a long-standing restricted government policy, to more prosperous economic conditions, and (3) the change in government policy towards active stimulation of urbanization and migration, in order to support non-agricultural growth. Hence, the assumptions about population growth are closely linked to the assumed regional development strategy.

Toth et al. (2003) have designed Chinagro population projections on the basis of cohort analysis, starting from assumptions at national level before disaggregating these to province level. Regarding the natural growth rate of population, the baseline supposes that national average fertility rates remain constant during the period 2000-2030 at levels of 1.98 and 1.58 in rural and urban areas, respectively, while average life expectancy rises with 4.5 years in rural areas and 3.5 years in urban areas. Regarding urbanization and migration, the baseline assumes a total net rural-to-urban migration of 288 million people in the period 2000-2030, of which 90 million (in each five-year period 15 million) are migrants to other provinces. Interprovincial migrants are assumed to come mainly from Sichuan, Anhui, Henan, Guangxi, Guizhou, Hunan and Heilongjiang, whereas Guangdong is the major province of destination (receiving more than half), followed by Shanghai and Beijing.

Table 4.3 presents the resulting population figures at regional level. Total population keeps on growing, at an average annual rate of 0.4%, reaching 1,459 million by 2030. Although the baseline fertility rate falls below reproduction level, the large share of young people in the population keeps numbers rising until 2040. Yet, at regional level a population decline can already be observed from 2020 onwards in Northeast, Central and Southwest, caused by high outflows from the rural areas to other provinces. Especially in Northeast the outflow is high, related to the restructuring of the old state-owned heavy industrial sector, which went along with massive lay-offs. Also in East the rural outflow is high but here many migrants stay in the own region. Population growth is highest in South, due to the enormous need for labor in this region with the highest projected non-agricultural growth rate. Furthermore, Plateau keeps a high population growth, due to a more relaxed population policy in this region.

In the medium variant of its most recent projections, the United Nation's Department of Economic and Social Affairs expects population to grow until 2030, reaching a level of 1.46 billion, and then to fall slightly to 1.41 billion in 2050. In the high variant population keeps on growing until a level of 1.65 billion in 2050, whereas in the low variant population remains below 1.38 billion, with the turning point around 2025 (UNDESA, 2006). Hence, Chinagro's baseline projection of 1.46 billion people in 2030 closely resembles the medium variant of the United Nations.

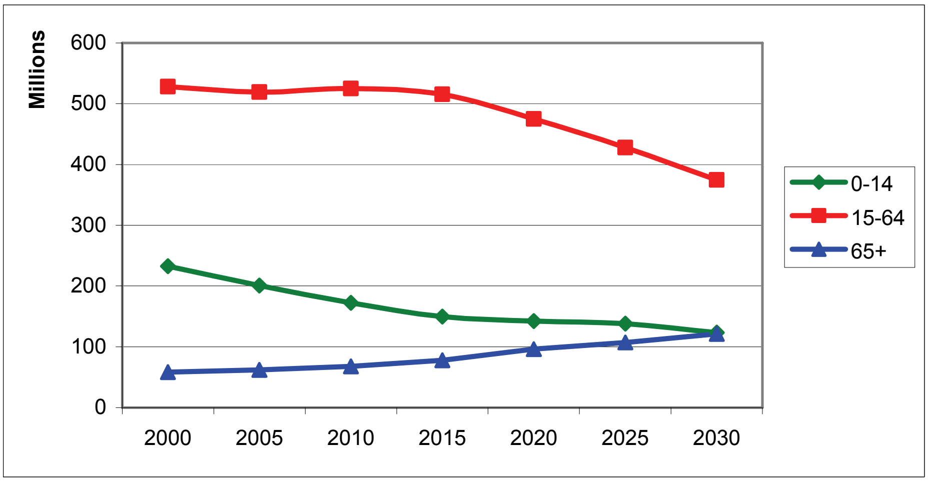
Table 4.3 Population growth in baseline

Region	Location	1997 population (millions)	Annual growth rate (in %) 1997-2003	2003-2010	2010-2020	2020-2030	**2003-2030**
North	Rural	209.82	-0.6	-0.7	-0.8	-1.4	**-1.0**
	Urban	94.50	3.1	2.6	1.9	1.7	**2.0**
	Total	304.33	0.7	0.6	0.4	0.1	**0.4**
Northeast	Rural	51.92	-0.7	-0.9	-1.0	-1.9	**-1.3**
	Urban	50.58	2.2	1.2	0.7	0.5	**0.8**
	Total	102.49	0.8	0.3	0.0	-0.3	**0.0**
East	Rural	115.21	-0.7	-1.0	-1.1	-1.8	**-1.3**
	Urban	76.82	2.8	2.1	1.5	1.3	**1.6**
	Total	192.04	0.8	0.5	0.3	0.1	**0.3**
Central	Rural	115.22	-0.6	-0.8	-0.9	-1.6	**-1.1**
	Urban	48.73	2.9	2.3	1.6	1.3	**1.7**
	Total	163.95	0.5	0.3	0.1	-0.2	**0.1**
South	Rural	98.70	-0.2	0.1	0.0	-0.8	**-0.3**
	Urban	71.40	3.3	3.3	2.5	2.3	**2.6**
	Total	170.10	1.3	1.6	1.4	1.1	**1.4**
Southwest	Rural	148.06	-0.5	-0.6	-0.8	-1.5	**-1.0**
	Urban	46.88	3.1	2.5	1.9	1.7	**2.0**
	Total	194.95	0.5	0.4	0.2	-0.1	**0.1**
Plateau	Rural	5.78	0.0	0.4	0.3	-0.5	**0.0**
	Urban	1.92	3.4	3.3	2.6	2.6	**2.8**
	Total	7.69	0.9	1.3	1.1	0.8	**1.0**
Northwest	Rural	76.30	-0.3	-0.1	-0.3	-1.0	**-0.5**
	Urban	32.75	3.1	2.7	2.1	1.9	**2.2**
	Total	109.05	0.8	0.9	0.7	0.4	**0.6**
China	**Rural**	**821.01**	**-0.5**	**-0.6**	**-0.7**	**-1.4**	**-0.9**
	Urban	**423.59**	**3.0**	**2.4**	**1.8**	**1.6**	**1.9**
	Total	**1244.60**	**0.7**	**0.7**	**0.5**	**0.2**	**0.4**

However, the predominant feature of the baseline is the acceleration of the current urbanization trend, in response to the labor needs of the non-agricultural sector. In each region rural population declines at increasing speed, leading to an urbanization level of 58% in 2030, hence including more than half of the population. For a proper interpretation of these figures, it must be mentioned that the Chinagro-model follows the definition of 'urban population' as used in the 2000 Population Census, which according to Liu et al. (2003) can be summarized as follows: (1) areas are designated as cities and towns on the basis of administrative rules that combine several types of criteria such as population density, employment, value added and infrastructural provisions, (2) cities and towns are subdivided into urban districts, (3) in urban districts with a population density higher than 1500 persons per km^2 the whole population is counted as urban, (4) in urban districts with a population density lower than 1500 persons per km^2 only people that live in streets, town sites or adjacent villages are counted as urban, (5) immigrants without official residence permit (hukou) who have resided in cities and towns longer than 6 months are included in the local urban population. Adopting this definition means that growth of the urban population in the projections of Table 4.3 is due both to natural growth and inflow of migrants and to anticipated reclassification of rural areas into urban areas.

Clearly, the declining numbers of rural population will put a strain on the availability of farm labor and make it necessary for agriculture to achieve significant increases in labor productivity through mechanization, land consolidation, economies of scale and technical innovations. We return to this aspect when discussing our assumptions on technical progress. The projections also indicate that the inevitable process of population ageing will be even faster in rural areas than average, due to the fact that most of the rural to urban migrants are from the most active, younger segment of the labor force. Figure 4.1 shows that by 2030 the share of people of 65 years and older will have increased in rural areas to about 20%, as opposed to a mere 13.5% in urban areas. Agricultural labor, to be specified in section 4.1.6 below, will follow the growth in rural population by province.

Figure 4.1 Trend of rural population by age class in baseline



Source: Toth et al. (2003)

4.1.3 World prices

The projections of future foreign trade prices are determined independently from the other elements of the baseline. First, we establish trends for the period 1997-2020. For grains, meat and dairy they are taken from the central price scenario in IFPRI's IMPACT model described by Rosegrant et al. (2001).[13] This scenario accounts for the effects of expected rises in meat consumption in Asia and other developing countries but does not take into consideration the possible future growth in demand for biofuel. For the remaining commodities we independently formulate assumptions for the year 2020 relative to 1997. Specifically, for 'other staple food', vegetable oil and sugar the price change in this period is assumed to be about the same as for food grains, whereas for carbohydrate feed and protein feed the trend follows the price change of feed grains. Fruits and, especially, vegetables are assumed to become cheaper relative to grains, due to

[13] In addition, for poultry meat we make a correction for an overestimated and, hence, not representative 1997 price, but this correction is neglected here.

expected worldwide export increases. For fish the price change in the period 1997-2020 is assumed to follow that of pork. Next, the 2030 price indices are obtained by extending the 1997-2020 trends, whereas the 2010 prices are derived from interpolation between the observations for 2003 and the longer-term trends, assuming for most commodities that prices will be back on their trend values by 2015.

The last step is to express all price trends relative to the increase of the unit value of Chinese manufacturing trade, by converting them from the unit value of international manufacturing trade to this unit. Thus, the foreign trade price of nonfood remains constant in the scenario. The resulting trends are shown in Table 4.4.

Table 4.4 Real* foreign price trends in baseline

Commodity	Price index (1997=100)					Annual growth 2003-2030 (in %)
	1997	2003	2010	2020	2030	
Milled rice	100.0	68.3	79.0	84.2	77.5	0.5
Wheat flour	100.0	96.0	93.1	88.6	83.6	-0.5
Maize	100.0	83.1	90.6	94.9	92.0	0.4
Other staple food	100.0	86.1	87.6	85.5	79.3	-0.3
Vegetable oil	100.0	87.2	88.1	85.5	79.3	-0.4
Sugar	100.0	76.1	83.3	85.5	79.4	0.2
Fruits	100.0	83.8	79.9	76.3	74.4	-0.4
Vegetables	100.0	69.5	63.1	60.2	58.8	-0.6
Ruminant meat	100.0	87.3	94.0	97.1	93.1	0.2
Pork	100.0	65.8	81.5	93.2	89.7	1.2
Poultry meat	100.0	66.5	81.2	91.8	87.7	1.0
Milk	100.0	96.9	92.1	85.5	79.4	-0.7
Eggs	100.0	69.6	83.3	92.7	89.1	0.9
Fish	100.0	67.2	82.0	92.6	89.0	1.0
Non-food excl feed	100.0	100.0	100.0	100.0	100.0	0.0
Carbohydrate feed	100.0	83.1	90.6	94.9	92.0	0.4
Protein feed	100.0	83.1	90.6	94.9	92.0	0.4

* Price trends are expressed relative to the trend of China's manufacturing export price

Comparing the years 1997, 2020 and 2030 only, one may see that all agricultural prices exhibit a steady decline, reflecting the general trend in IFPRI's price projections. However, we also account for the dramatic price fall for most commodities during the period 2000-2003 and the subsequent recovery that we take to last until 2020.[14] Consequently, a mixed picture emerges when one considers the period from 2003 to 2030. With the exception of dairy, the prices of animal products rise, and also feed prices rise. But for food crops there is a net decline in prices, except for rice and sugar. Farmers will take these relative price changes, in so far as transmitted to the domestic markets, into account when deciding on the allocation of labor inputs and cropping patterns.

[14] In view of the world price increases for grains and dairy of 2005 and 2006 (FAO, 2007b) the assumption of recovery by 2010 seems modest.

4.1.4 Availability of land and water

As discussed at some length in section 2, land reclamation and rehabilitation will continue providing some additional cropland in the coming decades but larger will be the losses to land degradation, ecological conversion programs and, most importantly, to urbanization and industrialization. Furthermore, the process of transformation of annual crop land into orchards will continue for a while. Water will become a pressing problem in the North region, whereas Northeast will have possibilities to expand its irrigation since it still has ample unused water available. These considerations are reflected in Table 4.5, following the same methodology as in Lu et al. (2004), at regional level. The model uses provincial growth rates applied at county level.

The baseline assumes that total farmland lost from conversion to built-up land is about 6 million hectare in the period 2003-2030, which is 4.5% of available crop land available nationwide in 2003. Yet, this national figure masks important differences among regions, with top shares of 10% and 15% in East and South, respectively. On average, two-thirds of crop land losses from conversion to built-up land are assumed to be compensated by newly reclaimed farmland, as long as such land is available in a province.

In total, Table 4.5 predicts a continued reduction in land planted to annual crops, albeit at a declining rate, from 125.6 million hectare in 2003 to 122.4, 119.4 and 116.6 million hectare in 2010, 2020 and 2030, respectively. During this period, the share of irrigated land in total rises from 46.6% in 2003 to 47.9% in 2030, mainly due to the expansion in the Northeast. In all other regions both irrigated and rainfed areas are being reduced.

Conversion to built-up land is the main factor driving the reduction of farmland in the coastal North, East and South regions, with their rapidly growing urban population and non-agricultural sector. From 2003 to 2030, the absolute decline in annual crop land in these regions is 2.4, 1.5 and 1.9 million hectare, respectively. Conversion programs to restore ecologically fragile cultivated land is the main reason for the changes in the Central, Southwest and Northwest regions with net declines of annual crop land of 0.7, 0.9 and 1.6 million hectare, respectively. Part of this loss of annual crop land is due to conversion into orchards that increases in the baseline from 2003 to 2030 by 2.3 million hectare, especially in the North.

Table 4.5 Available cropland: growth rates in baseline

Region	Type of land	1997 area (million ha)	Annual growth rate (in %) 1997-2003	2003-2010	2010-2020	2020-2030	**2003-2030**
North	Irrigated	17.232	-0.51	-0.53	-0.21	-0.19	**-0.29**
	Rainfed	12.137	-0.64	-0.67	-0.34	-0.29	**-0.41**
	Orchard	2.008	2.37	2.06	1.23	0.81	**1.29**
	Total	31.377	-0.36	-0.37	-0.12	-0.12	**-0.19**
Northeast	Irrigated	3.944	0.71	0.67	1.60	1.60	**1.36**
	Rainfed	16.681	0.08	0.08	-0.61	-0.71	**-0.47**
	Orchard	0.678	1.72	1.54	0.72	0.52	**0.86**
	Total	21.304	0.25	0.25	-0.09	-0.08	**0.00**
East	Irrigated	9.882	-0.40	-0.41	-0.40	-0.43	**-0.41**
	Rainfed	3.827	-0.41	-0.42	-0.25	-0.25	**-0.29**
	Orchard	1.324	0.36	0.36	0.55	0.28	**0.40**
	Total	15.032	-0.33	-0.34	-0.26	-0.31	**-0.30**
Central	Irrigated	8.043	-0.43	-0.44	-0.14	-0.11	**-0.21**
	Rainfed	3.866	-0.54	-0.56	-0.27	-0.22	**-0.33**
	Orchard	1.047	1.02	0.96	0.52	0.40	**0.59**
	Total	12.956	-0.34	-0.35	-0.12	-0.09	**-0.17**
South	Irrigated	5.413	-0.68	-0.71	-0.88	-0.96	**-0.87**
	Rainfed	4.623	-0.54	-0.56	-0.77	-0.82	**-0.73**
	Orchard	2.292	0.12	0.12	-0.09	-0.45	**-0.17**
	Total	12.327	-0.48	-0.49	-0.67	-0.80	**-0.67**
Southwest	Irrigated	6.387	-0.46	-0.47	-0.16	-0.13	**-0.23**
	Rainfed	12.095	-0.26	-0.26	-0.16	-0.13	**-0.18**
	Orchard	1.241	2.04	1.81	0.75	0.56	**0.96**
	Total	19.723	-0.17	-0.17	-0.08	-0.07	**-0.10**
Plateau	Irrigated	0.391	0.04	0.04	-0.05	-0.05	**-0.03**
	Rainfed	0.644	-0.05	-0.04	-0.06	-0.05	**-0.05**
	Orchard	0.008	0.00	0.00	0.00	0.00	**0.00**
	Total	1.043	-0.02	-0.01	-0.06	-0.05	**-0.04**
Northwest	Irrigated	8.703	-0.30	-0.31	-0.16	-0.14	**-0.19**
	Rainfed	14.820	-0.72	-0.75	-0.17	-0.15	**-0.32**
	Orchard	0.624	4.70	3.60	1.23	0.86	**1.70**
	Total	24.148	-0.41	-0.42	-0.10	-0.09	**-0.18**
China	**Irrigated**	**59.995**	**-0.38**	**-0.38**	**-0.13**	**-0.09**	**-0.18**
	Rainfed	**68.694**	**-0.38**	**-0.39**	**-0.36**	**-0.36**	**-0.37**
	Orchard	**9.222**	**1.47**	**1.34**	**0.69**	**0.41**	**0.76**
	Total	**137.911**	**-0.25**	**-0.25**	**-0.17**	**-0.17**	**-0.19**

For grassland the baseline supposes steady but moderate decreases in surfaces in all coastal regions, and more or less constant surfaces inland, leading to an overall loss of 9 million hectare during the period 2003-2030. However, in terms of grass output the net trend is positive since the area of improved, sown grassland, with a yield five to eight times as high as the yield on natural grassland is assumed to increase by 5% annually, from 5.6 million hectare in 2003 to 21.9 million hectare in 2030. Table 4.6 summarizes the baseline growth rates for grassland.

Table 4.6 Available grassland: growth rates in baseline

Region	Type of grassland	1997 area (million ha)	Annual growth rate (in %) 1997-2003	2003-2010	2010-2020	2020-2030	**2003-2030**
North	Natural	14.481	-1.0	-1.5	-1.3	-0.9	-1.2
	Sown	0.646	0.2	11.3	4.3	3.0	5.6
	Total	15.127	-0.9	-0.7	-0.6	-0.2	-0.5
Northeast	Natural	13.700	-0.4	-0.5	-0.4	-0.2	-0.4
	Sown	0.480	0.6	4.9	2.6	2.1	3.0
	Total	14.180	-0.4	-0.3	-0.2	-0.1	-0.2
East	Natural	3.906	-1.7	-1.4	-1.3	-0.6	-1.0
	Sown	0.090	3.6	6.2	3.3	2.7	3.8
	Total	3.996	-1.5	-1.1	-1.0	-0.3	-0.8
Central	Natural	14.585	-0.1	-0.2	-0.2	-0.1	-0.2
	Sown	0.151	4.5	8.8	4.0	3.1	4.9
	Total	14.737	-0.1	0.0	0.0	0.0	0.0
South	Natural	11.978	-0.6	-0.5	-0.5	-0.2	-0.4
	Sown	0.096	3.6	8.0	3.8	3.0	4.6
	Total	12.074	-0.6	-0.4	-0.4	-0.1	-0.3
Southwest	Natural	35.306	0.0	-0.1	-0.1	-0.1	-0.1
	Sown	0.142	-1.5	16.0	5.0	3.3	7.1
	Total	35.448	0.0	0.0	0.0	0.0	0.0
Plateau	Natural	102.377	0.0	-0.1	-0.1	-0.1	-0.1
	Sown	0.194	0.4	25.8	6.1	3.8	10.0
	Total	102.571	0.0	0.0	0.0	0.0	0.0
Northwest	Natural	134.645	-0.3	-0.6	-0.4	-0.3	-0.4
	Sown	3.874	-0.5	9.1	3.8	2.7	4.7
	Total	138.519	-0.3	-0.2	-0.2	-0.1	-0.1
China	**Natural**	**330.979**	-0.2	-0.4	-0.3	-0.2	-0.3
	Sown	**5.672**	0.0	10.1	4.1	2.9	5.1
	Total	**336.652**	-0.2	-0.1	-0.1	0.0	-0.1

4.1.5 Stable capacities

As discussed in section 2, China is rapidly moving from traditional natural resource based management to intensified peri-urban and urban production systems, in response to the growing demand for livestock products. It is very hard to predict the future geographical distribution of the intensified livestock production in any detail, because unlike crop cultivation and grazing this sector tends to be footloose, and shifts in location will be determined by a wide array of factors, including developments in infrastructure, availability of feed, changes in relative scarcities of land, labor and capital, and the severity and enforcement of environmental regulations. This also motivates our treating of stable capacities as scenario variables that seem plausible given the population projections, demand growth scenarios for animal products, and consideration of environmental factors, while leaving it to the endogenous supply response of the model to determine the actual intensity of production based on prices, feed availability and other factors such as the availability of manpower. Stable capacities are expressed in numbers of standard animal places. For each land use type, a specific standard animal is defined. Animal numbers are converted into this unit on the basis of their annual energy intake (or potential annual energy intake in case their life is shorter).

Rather than being purely exogenous, the projected trends have been generated, at provincial level, through simulations outside the Chinagro welfare model, for different livestock management systems, on the basis of three principles described in Ermolieva et al. (2005): (i) the future distribution of livestock in confined[15] traditional systems is linked to projected changes in rural population; (ii) the geographical distribution and level of pastoral livestock follows the projected trends of the availability and productivity of grasslands, hence taking account of planned grassland improvement and rehabilitation to increase productivity above current natural conditions; and (iii) the number of animal places (stable units) in confined specialized and industrial livestock systems is expanding to compensate for decreases in traditional systems and to meet (approximately) the substantial growth in demand that is anticipated at provincial level.[16]

The resulting baseline growth rates, aggregated to regional level, are shown in Tables 4.7 and 4.8, for ruminants and non-ruminants, respectively. Confined ruminant livestock systems rise relative to pastoral systems, as grassland resources are already under great pressure and significant expansion of grass-based livestock systems would require major efforts beyond those assumed in the baseline, to rehabilitate degraded pastures and to improve grassland productivity. Table 4.6 indicates that the baseline supposes that modest efforts are made in this direction.

At the same time, for draught animals, which include all animals used in transportation, a marked decline is projected from 66.4 million units in 1997 to 41.2 millions in 2030. The rate of decline is rather uniform across regions, except in the sparsely populated, accidented and less developed Plateau and Northwest, where the number of draught animals keeps on rising until 2010, when a decline sets in.

That the number of animal units in “traditionally mixed” ruminant sector is growing by as much as 2.3% annually over the period 2003-2030 in the baseline might be surprising given the pressure on the land alluded to earlier but this is because the sector includes all intensified cattle meat production, for which we expect the number of livestock places to rise. For milk cattle, there is a separate intensified land use type in the model, whose capacity grows from 1.7 million places in 2003 to 4.7 million places in 2030, largely in North, Northeast and Northwest.

[15] Confined livestock systems allow for 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.

[16] For the provinces Beijing and Shanghai where cultivated land is very scarce, reallocation of the intensive production has been assumed at a rate proportional to projected reduction of farmland.

Table 4.7 Stable capacities of ruminants, in million standard animal places: growth rates in baseline

Region	Type of ruminant system	1997 capacity (million places)	Annual growth rate (in %) 1997-2003	2003-2010	2010-2020	2020-2030	**2003-2030**
North	Draught	13.83	-0.8	-1.3	-1.8	-2.5	**-1.9**
	Grazing	1.64	0.5	1.0	1.1	1.0	**1.1**
	Trad. mixed	20.50	0.3	2.5	1.9	1.1	**1.8**
	Spec. milk	0.20	21.5	6.7	2.9	1.5	**3.4**
Northeast	Draught	5.59	-0.9	-1.5	-2.0	-2.9	**-2.2**
	Grazing	1.77	0.4	0.3	0.4	0.5	**0.4**
	Trad. mixed	5.78	0.5	1.9	1.3	0.3	**1.1**
	Spec. milk	0.25	8.0	5.9	2.3	0.8	**2.7**
East	Draught	4.04	-1.1	-1.9	-2.5	-3.3	**-2.7**
	Grazing	0.33	-1.2	1.2	1.0	0.6	**0.9**
	Trad. mixed	4.80	-0.2	1.6	1.2	0.2	**0.9**
	Spec. milk	0.09	12.2	4.9	2.1	1.0	**2.4**
Central	Draught	8.42	-0.8	-1.5	-2.1	-2.9	**-2.2**
	Grazing	1.16	0.2	-0.3	0.0	0.2	**0.0**
	Trad. mixed	1.82	0.9	1.3	0.8	0.0	**0.6**
	Spec. milk	0.01	17.3	9.8	3.6	1.5	**4.3**
South	Draught	9.98	-0.3	-0.8	-1.3	-2.4	**-1.6**
	Grazing	0.85	-0.3	-0.3	-0.1	0.2	**-0.1**
	Trad. mixed	1.64	1.1	2.6	1.6	0.8	**1.5**
	Spec. milk	0.03	8.2	6.7	3.3	2.0	**3.7**
Southwest	Draught	15.01	-0.6	-1.1	-1.7	-2.4	**-1.8**
	Grazing	7.58	0.2	0.6	0.5	0.6	**0.6**
	Trad. mixed	7.73	0.6	3.2	2.0	1.1	**2.0**
	Spec. milk	0.02	27.9	13.9	4.6	2.4	**6.1**
Plateau	Draught	1.02	0.2	0.2	-0.1	-0.5	**-0.2**
	Grazing	16.21	0.1	0.4	0.4	0.4	**0.4**
	Trad. mixed	1.60	4.6	13.4	5.8	3.2	**6.7**
	Spec. milk	0.01	10.3	31.1	6.7	3.5	**11.3**
Northwest	Draught	8.55	0.3	0.1	-0.2	-0.6	**-0.3**
	Grazing	15.73	1.1	0.9	0.9	0.9	**0.9**
	Trad. mixed	8.45	2.9	4.8	3.4	1.8	**3.2**
	Spec. milk	0.12	18.8	10.9	4.3	2.2	**5.2**
China	**Draught**	**66.43**	**-0.5**	**-1.1**	**-1.5**	**-2.2**	**-1.6**
	Grazing	**45.27**	**0.5**	**0.6**	**0.6**	**0.6**	**0.6**
	Trad.mixed	**52.33**	**1.0**	**3.4**	**2.4**	**1.3**	**2.3**
	Spec. milk	**0.71**	**15.5**	**8.0**	**3.3**	**1.7**	**3.9**

For non-ruminants (pigs and poultry), the model distinguishes two land use types, one traditional covering the mixed backyard production and one intensified covering production of specialized households as well as industrial farms. The stable capacities of these systems are expressed in pig places. As mentioned earlier, the capacities in the traditional sector are assumed to follow the rural population. Hence, the stable capacity of this sector falls by about one percent annually during the period 2003-2030, as shown in Table 4.8. The intensified sector more than compensates for this decline not so much in stable capacities but because of the shift to intensive production, with a rise of 2.8%, especially in the period until 2010.

These growth rates imply that the ratio of traditional to modern non-ruminant animal places fall from 2.8 in 2003 to about 1.0 in 2030 when each has about 270 million animal places in pig-equivalents. In all, the regional distribution of the intensified stable capacity follows population rather closely. By 2030, the share in animal places differs from the population share by less than one percentage-point in four of the eight regions with differences largest in Northeast (3.5% higher) and Northwest (3.3% higher).

Table 4.8 Stable capacities of pigs and poultry, in million standard animal places: growth rates in baseline

Region	Type of management*	1997 capacity (million places)	Annual growth rate (in %) 1997-2003	2003-2010	2010-2020	2020-2030	**2003-2030**
North	Trad. mixed	75.01	-0.8	-0.8	-0.9	-1.5	**-1.1**
	Intensified	21.16	6.3	5.0	2.3	1.3	**2.6**
Northeast	Trad. mixed	30.10	-1.1	-1.1	-1.0	-1.9	**-1.4**
	Intensified	11.09	5.6	4.7	2.1	1.0	**2.4**
East	Trad. mixed	41.44	-1.1	-1.1	-1.1	-1.8	**-1.4**
	Intensified	14.50	5.6	4.4	1.6	1.1	**2.1**
Central	Trad. mixed	57.08	-0.9	-0.9	-1.0	-1.7	**-1.2**
	Intensified	10.90	6.7	6.5	2.7	1.2	**3.1**
South	Trad. mixed	41.79	-0.1	-0.1	0.0	-0.8	**-0.3**
	Intensified	13.37	6.4	6.2	3.2	2.1	**3.5**
Southwest	Trad. mixed	107.94	-0.8	-0.8	-0.8	-1.6	**-1.1**
	Intensified	13.01	6.2	5.4	2.6	1.4	**2.9**
Plateau	Trad. mixed	1.14	0.2	0.2	0.1	-0.6	**-0.1**
	Intensified	0.11	6.6	8.6	4.2	2.9	**4.8**
Northwest	Trad. mixed	22.13	-0.4	-0.4	-0.5	-1.3	**-0.8**
	Intensified	3.79	6.5	7.2	3.6	2.3	**4.0**
China	**Trad.mixed**	**376.63**	**-0.8**	**-0.7**	**-0.8**	**-1.5**	**-1.0**
	Intensified	**87.93**	**6.2**	**5.4**	**2.5**	**1.4**	**2.8**

* Intensified captures specialized households and industrial systems.

4.1.6 Farm labor and machinery

Baseline trends in labor availability and mechanization are summarized in Table 4.9. In each province, available farm labor is assumed to change in proportion with the rural population (regional rates of change may be slightly different due to aggregation). Hence, the baseline has a general decline in farm labor, on average one percent annually between 2003 and 2030, but at accelerating speed, especially after 2020. Agricultural machinery affects cropping only. For the livestock sector, the machinery is taken to be part of the livestock system itself and labor saving operates, to a large extent, via the transition to more intensified production. The period 1997-2003 witnessed high rates of growth of available machinery, ranging from 3.7% annually in the South to 7.5% in the North. After that, the baseline is supposed to follow a more modest but sustained growth path at an average of 3.1% annually, with rates highest in Central, Southwest and Plateau.

Table 4.9 Farm labor and crop machinery: growth rates in baseline*

Region	Type of resource	1997 level	Annual growth rate (in %)				
			1997-2003	2003-2010	2010-2020	2020-2030	**2003-2030**
North	Farm labor	61.73	-0.6	-0.7	-0.8	-1.5	**-1.0**
	Crop machinery	131.80	7.5	2.5	2.5	2.5	**2.5**
Northeast	Farm labor	12.91	-0.7	-0.9	-1.0	-1.9	**-1.3**
	Crop machinery	19.15	6.5	3.0	3.0	3.1	**3.0**
East	Farm labor	36.78	-0.7	-1.0	-1.1	-1.8	**-1.3**
	Crop machinery	54.22	4.9	2.7	2.7	2.7	**2.7**
Central	Farm labor	34.16	-0.6	-0.8	-0.9	-1.6	**-1.2**
	Crop machinery	28.43	6.9	4.0	4.0	4.0	**4.0**
South	Farm labor	31.81	-0.3	-0.1	-0.1	-0.9	**-0.4**
	Crop machinery	26.99	3.7	3.8	3.8	3.8	**3.8**
Southwest	Farm labor	51.76	-0.5	-0.6	-0.8	-1.5	**-1.0**
	Crop machinery	24.76	6.6	4.0	4.0	4.0	**4.0**
Plateau	Farm labor	1.46	0.0	0.4	0.3	-0.5	**0.0**
	Crop machinery	1.74	5.8	4.0	4.0	4.0	**4.0**
Northwest	Farm labor	22.39	-0.3	-0.2	-0.4	-1.1	**-0.6**
	Crop machinery	29.42	6.8	3.6	3.6	3.7	**3.6**
China	**Farm labor**	**253.00**	**-0.5**	**-0.6**	**-0.7**	**-1.4**	**-1.0**
	Crop machinery	**316.50**	**6.5**	**3.0**	**3.1**	**3.1**	**3.1**

* Labor is expressed in million man-years (full-time equivalent), machinery in million KW and animal power whose availability follows from the stable capacity of the draught animal sector also in million KW. The Chinagro model works with the concept of 'equipped labor' which is labor equipped with animal and/or machine power.

4.1.7 Technical change in agriculture

The baseline assumptions about technical progress in agriculture are defined against the background of labor availability and mechanization of Table 4.9. The scenario simulations distinguish three types of technical progress, (a) labor efficiency: labor-saving technical progress expressed as increase in productivity of one unit of equipped labor (i.e. labor equipped with machinery and draught animals), (b) output efficiency: output of specified commodities per unit of aggregate output, at given prices; for given land use type we take progress to be Solow neutral, letting all outputs increase at the same rate, and (c) input efficiency: reduction in amount of fertilizer and animal feed needed to obtain a given (aggregate) yield by land use type.

While difficult to quantify, the rates of progress are highly correlated with agricultural R&D investment. Table 4.10 shows the assumptions for the baseline that are kept constant over the whole period. The baseline abstracts from increases in input efficiency.

Table 4.10 Annual rates of technical progress in agriculture in baseline (1997-2030)

Land use type	Rate of labor-saving technical progress	Rate of Solow-neutral technical progress
Cropping (irrigated, rainfed)		
All regions excl. Northeast	0.8%	0.2%
Northeast	1.0%	0.2%
Cropping (orchards)		
All regions excl. Northeast	0.8%	-
Northeast	1.0%	-
Livestock (ruminants)		
Draught	0.5%	-
Grazing	0.5%	0.3%
Traditionally mixed	0.5%	-
Specialized dairy	0.3%	0.8%
Livestock (pigs and poultry)		
Traditionally mixed	0.5%	0.8%
Intensified	0.3%	0.8%

The table shows that labor-saving technical progress is assumed to be the dominant type in cropping (especially in the Northeast). In livestock farming technical progress is mainly of the Solow-neutral type, in conjunction with the intensification represented by the trends in stable capacities. These various kinds of technical progress affect yields jointly with other drivers such as prices and also the availability of land and stable capacity that determines to which extent progress in input productivity is hampered as yields come closer to technological ceilings. The baseline appears to induce modest but steady increases of crop yields per hectare of about 0.6 percent on average annually, on both irrigated and rainfed land. Although somewhat higher than the rates suggested in World Bank (2006), increases of this order of magnitude seem plausible for a baseline scenario, especially since the yield improvements in the Chinagro model also cover increases in the multiple-cropping index. For livestock, the yield changes per animal place appear to be around 0.4% for ruminants and around 1.2% for non-ruminants.

In addition to these sector-wide forms of technical progress, the baseline specifies improvements in specific crop or livestock activities, implemented through changes in the mapping from aggregate output to tradable model commodities (shown in Appendix A). Specifically, it introduces the following adjustments:

- improved processing of sugarcane, sugar beet and soybean in the period 1997-2010, raising output by 10 to 20% in total,
- gradual shift towards more soybean processing at the expense of direct consumption, reducing the food share annually by 1%,
- gradual decline (0.3% annually) in the conversion of root crops and vegetables into carbohydrate feed, reflecting stricter sanitary regulations,

- gradual increase of the meat output of traditional cattle, goat and sheep (0.5% annually) reflecting a gradually participation of modern enterprises.

Furthermore, losses in trade and transportation are assumed to increase as exogenous demand at a modest annual rate of 0.5%, with higher rates for fast-growing perishable commodities such as fruits and vegetables (0.7%) and, especially, milk and fish (2.5%). This reflects the rise in trade volumes, but is not treated as a fraction of trade because it is assumed that the expanded trade will benefit from improved preservation techniques.

Finally, we mention that the baseline keeps the efficiency of local inputs such as manure and crop residuals unchanged, whereas from 2010 onwards the share of household waste that is converted into feed is reduced annually by 5%, reflecting tightening up of the sanitary rules.

4.1.8 Agricultural markets

The baseline considers market policies and reforms as well as changes in trade and transport costs.[17] Market policies and reforms distinguish interventions on foreign trade from those on domestic transactions. Since the 1980s, China's foreign trade policies have been characterized by a gradual integration in the international agricultural trade system, culminating in the WTO-accession in December 2001. The baseline supposes that this trend of opening up and liberalization is to continue and builds existing agreements and commitments regarding tariffs and quota into the scenario assumptions. Table 4.11 summarizes the specification, building on Huang (2002) and Huang, Rozelle and Chang (2004).

Import tariffs consist of three elements: applied official tariffs, differences with the effective domestic value added tax and non-tariff barriers. In the historical period 1997-2003, the applied tariffs are rather low for grains, root crops and soybean but high (20% and more) for other crops and livestock products, the value added tax rate on imports (13% to 15%) is much higher than the domestic rate, and various non-tariff barriers exist mainly for oilseeds, sugar and maize. The baseline assumes separate trends for these three elements: (a) applied tariffs are halved from 2003 to 2010 and kept constant afterwards, (b) the value added tax difference gradually vanishes due to increases in the domestic rate, and (c) the non-tariff barriers are halved from 2003 to 2010 and then phased out. In all this leads to a rather flat rate of reduction for most commodities of about 2% annually and the resulting 2030 rates range from 8.5% for grains to 20% for sugar. There are no import tariffs on the composite commodities carbohydrate feed and protein feed.

[17] Actually, the scenario was formulated in 2004. In hindsight, the pace of tariff and tax reduction assumed for the period 2003-2010 is rather modest, especially for domestic taxes.

Table 4.11 Agricultural tariff rates* on foreign trade in baseline

Commodity	Tariff rate (in %)					Annual growth 2003-2030 (in %)
	1997	2003	2010	2020	2030	
Import tariffs						
Milled rice	17.0	14.0	11.5	10.0	8.5	-1.8
Wheat flour	5.0	14.0	11.5	10.0	8.5	-1.8
Maize	7.0	14.0	11.5	10.0	8.5	-1.8
Other staple food	25.0	15.0	12.0	10.5	9.0	-1.9
Vegetable oil	47.0	23.0	15.5	14.0	12.5	-2.2
Sugar	50.0	36.0	23.0	21.5	20.0	-2.2
Fruits	50.0	27.0	19.0	17.5	16.0	-1.9
Vegetables	50.0	27.0	19.0	17.5	16.0	-1.9
Ruminant meat	60.0	27.0	19.0	17.5	16.0	-1.9
Pork	35.0	27.0	19.0	17.5	16.0	-1.9
Poultry meat	35.0	25.0	18.0	16.5	15.0	-1.9
Milk	23.5	28.0	20.5	19.0	17.5	-1.7
Eggs	33.0	23.0	16.0	14.5	13.0	-2.1
Fish	27.0	25.0	17.0	15.5	14.0	-2.1
Carbohydrate feed	0.0	0.0	0.0	0.0	0.0	0.0
Protein feed	0.0	0.0	0.0	0.0	0.0	0.0
Export tariffs						
Milled rice	8.0	4.0	3.0	1.5	1.5	-3.6
Wheat flour	5.0	3.0	2.2	1.1	1.1	-3.6
Fruits	10.0	5.0	3.8	1.9	1.9	-3.5
Vegetables	10.0	5.0	3.8	1.9	1.9	-3.5
Ruminant meat	8.0	4.0	3.0	1.5	1.5	-3.6
Pork	20.0	10.0	7.5	3.7	3.7	-3.6
Poultry meat	6.8	8.0	6.0	3.0	3.0	-3.6
Eggs	4.0	2.0	1.5	0.8	0.8	-3.3
Fish	15.0	8.0	6.0	3.0	3.0	-3.6

* Import tariffs: applied tariff plus difference in value added tax (compared to domestic) and non-tariff barriers.
Export tariffs: implicit tariff minus domestic tax rebates and applied subsidies.

Export tariff rates appear in the table only for commodities with significant commercial exports. These rates are also built up from three elements: (a) applied official subsidies, (b) rebates of domestic taxes and (c) estimates of implicit tariffs, where (c) is relatively high and dominant. The baseline assumes that the applied subsidies are abolished after 2003, whereas the tax rebates remain unchanged and the implicit tariffs are reduced by two thirds from 2003 to 2020 and kept constant afterwards. As shown in Table 4.11, these assumptions lead to a rather uniform annual decline of 3.5% for most commodities, starting from already low export tariff rates in 2003.

The table does not include the subsidies on maize exports provided in 2003 that were quite substantial at the time and related to the policy of reducing exceptionally high stock levels, by a 15 million ton one-time subsidized export. For wheat and rice similar huge stock decreases were realized but without large export volumes causing the domestic market to become flooded with wheat and rice and leading, together with low international prices and reduced government support in grain marketing, to depressed prices. By early 2004 the situation changed, worried as policy makers had become about the fall in rice and wheat output in previous years.

Domestic tax rates are assumed to capture the combined effect of local taxes and procurement policies that historically have effectively acted also as taxes on farmers (Huang and Rozelle, 2004), even though both are hard to quantify. Local taxes to a significant extent depend on power relations in villages and are, therefore, not recorded accurately by central government, nor controlled by it, whereas procurement rules and prices have been subject to frequent changes, as mentioned earlier in section 2. For 1997, CCAP estimates effective tax rates nationwide at 8% for grain and 12% for other commodities, as shown in Table 4.12. Since then, the policy trend is towards a reduction of the burden on farmers, witness the rural 'tax-for-fee' reform introduced in 2002-2003 after a pilot project in Anhui province (Yep, 2004), and the introduction of grain subsidies in 2004 to prevent another serious fall in supply (Gale et al., 2005). These changes are represented in the baseline through a general decline of tax rates until 2010, which are kept constant afterwards. By that time, tax rates will have halved to reach a level of 5% for most commodities and a level of 3% for oil and sugar. For grains, the conversion of taxes into subsidies is represented via a subsidy rate of 5% throughout the period. Under the WTO rules a domestic subsidy of up to 8.5% would be possible but it is assumed that government will not fully fill this room.

In Table 4.12 the baseline taxes are shown. The 2003 rate for grains is an outlier and an exception. It does not represent an official tax measure but amounts to an imputed rate that was introduced to reflect the generally unfavorable situation for grain farmers in the early years of the 21st century, in part reflecting their contribution, directly or indirectly, to the financing of the huge stock disposal costs during these years.

Table 4.12 Agricultural domestic tax rates in baseline

Commodity	Tax rate (in %)				
	1997	2003	2010	2020	2030
Producer taxes					
Milled rice	8.0	12.0	-5.0	-5.0	-5.0
Wheat flour	8.0	12.0	-5.0	-5.0	-5.0
Maize	8.0	12.0	-5.0	-5.0	-5.0
Other staple food	8.0	8.0	4.0	0.0	0.0
Vegetable oil	12.0	6.0	3.0	3.0	3.0
Sugar	12.0	6.0	3.0	3.0	3.0
Fruits	12.0	10.0	5.0	5.0	5.0
Vegetables	12.0	10.0	5.0	5.0	5.0
Ruminant meat	12.0	10.0	5.0	5.0	5.0
Pork	12.0	10.0	5.0	5.0	5.0
Poultry meat	12.0	10.0	5.0	5.0	5.0
Milk	12.0	10.0	5.0	5.0	5.0
Eggs	12.0	10.0	5.0	5.0	5.0
Consumer taxes on food					
Rural	0.0	0.0	1.0	2.0	3.0
Urban	1.0	1.0	2.0	3.5	5.0

The consumer tax rates in Table 4.12 give a simplified representation of the pattern foreseen after effective introduction of value added taxes. They are applied across-the-board, hence without regional or group-specific differences.

Turning from market policies and reform to trade and transport costs, we mention that infrastructural improvements are kept modest in the baseline but taken to reduce the trade and transport costs on foreign trade by 0.5% annually, with for vegetables, fruits, meat and fish that have large trade margins in the base year, an additional reduction of around 30% during the period 1997-2010. Trade and transport costs between farmers and regional market places remain unchanged in the baseline, except for specific improvements in oil and sugar marketing. Trade and transport costs between regions are kept unchanged as well. In addition, as an incidental shift, the general worsening of rice and wheat marketing conditions around 2003, referred to earlier, is represented by a temporary increase of domestic trade margins for 2003 only.

Finally, regarding foreign trade two additional mechanisms should be mentioned. One is that for vegetables, an upper bound is imposed on the volumes the world market can absorb. These are relaxed in the baseline from 5.2 million ton in 2003 (i.e. about 10% of total world trade in vegetables) to 10.1 million ton in 2010 and then after that by 2% annually. The other is that for fish, the model assumes a committed export volume of 1.4 million ton in 2003 reflecting the heterogeneity of this commodity, which is not sufficiently captured in the commodity classification of the model itself. In the baseline the committed fish export volume grows with 0.5% annually.

4.1.9 Consumer demand patterns and life style

As discussed earlier, consumption of meat and eggs has risen fast in the last two decades, due to the growth in per capita incomes and the changes in lifestyle especially related to migration from rural to urban areas. The baseline takes this trend to continue in line with the persistent growth in non-agricultural output and the sustained rural-to-urban migration specified earlier in Tables 4.1 and 4.3.

Recall from the discussion in section 3.1 that in the Chinagro model consumer expenditures on agricultural goods obey a linear expenditure system, hence with committed and uncommitted expenditures, corresponding to a Stone-Geary utility function that appears as the nonlinear component in a quasilinear utility function. The quasilinearity implies that the utility functions are expressed in money metric and, therefore, effectively apply a conversion by multiplication through a welfare weight. Scenario parameters are now these welfare weights, population numbers and the budget shares of the uncommitted expenditures, for each urban and rural income class. Per capita committed consumption volumes are kept constant.

Since showing the shifts in model coefficients actually introduced in the model would not be very informative, and because consumer demand is so significantly driven by the exogenous growth of non-agricultural income, we describe the baseline specification in terms of total uncommitted expenditures on food (Table 4.13) and their distribution across commodities (Table 4.14), albeit that these items are to some extent endogenous within the model.

We also recall that combined, the model's price normalization on a fixed non-agricultural price, and the quasilinearity of the utility functions ensure that these expenditures can be interpreted as "real" and comparable to the 1997 expenditure levels.

Table 4.13 shows the development of total uncommitted food expenditures, by region and for rural and urban separately, and also mentions the sum of committed and uncommitted food expenditures in the base year as background. The larger part of food expenditures, around 60-70 percent, is in fact committed, and changes over time merely due to endogenous price changes in the model. Hence, the baseline leaves about two-thirds of base year food intake volumes unaffected. For the remaining one-third, uncommitted demand, steady per capita increases are projected that do not differ much between regions, and are higher for urban than for rural consumers, about 3% versus 2.5%, and gradually decline over time. On average, for rural classes the resulting per capita uncommitted food expenditures are in 2030 about twice as high as in 2003, and for urban classes about 2.2 times as high. We add that the consumption levels were checked against their nutritional content in calories, and shifts are such that a reasonable nutritional balance is maintained.

Table 4.13 Food expenditures in baseline

Region	Location	1997 food expenditures in Yuan/person/year		Annual growth of uncommitted per capita food expenditures (in %)			
		Total	Uncommitted	1997-2003	2003-2010	2010-2020	2020-2030
North	Rural	931.4	317.5	3.7	2.5	2.5	2.4
	Urban	2090.9	689.2	4.2	3.2	3.2	3.0
Northeast	Rural	1042.0	410.3	3.6	2.3	2.3	2.2
	Urban	1813.1	628.9	4.0	3.0	3.0	2.7
East	Rural	1350.3	483.0	4.0	2.6	2.6	2.6
	Urban	3062.8	916.5	4.2	3.1	3.1	2.8
Central	Rural	1120.1	396.6	3.6	2.3	2.3	2.1
	Urban	2078.8	674.3	4.1	3.1	3.1	2.9
South	Rural	1551.6	532.8	4.0	2.6	2.6	2.4
	Urban	2966.3	734.8	4.3	3.4	3.4	3.3
Southwest	Rural	1033.1	404.3	3.6	2.0	1.9	1.7
	Urban	2216.6	665.8	4.2	3.2	3.2	3.0
Plateau	Rural	922.2	371.7	5.7	2.1	1.9	1.7
	Urban	1858.6	479.4	5.3	3.4	3.4	3.3
Northwest	Rural	705.0	281.4	3.8	2.5	2.4	2.3
	Urban	1727.2	649.4	4.0	3.0	3.0	2.7

On the basis of Table 4.14, we may look at these trends in more detail, for individual commodities and by income group (for all regions together). Two features stand out. First, one may note the important rise in consumption of meat, milk, eggs and fish, partly at the expense of the consumption of crops. Uncommitted meat expenditure levels are in 2030 for all classes two to three times as high as in 2003. At the same time, uncommitted expenditures on crops fall slightly with the exception of fruits and vegetables in rural areas and maize in urban areas. Second, the table shows increasing disparity in food consumption patterns, due to the fact that the rich become richer faster than the poor. Yet, the baseline assumes that government manages to contain the food expenditure gap. Under constant prices total food expenditures of the urban high income group in 2030 would be 1.6 times as high as in 2003, whereas the ratio would be 1.2 for the rural low income group.

Table 4.14 Annual growth (in %) of uncommitted per capita food expenditures by commodity, baseline, 2003-2030

Commodity	Rural low	Rural middle	Rural high	Urban Low	Urban middle	Urban High
Milled rice	-0.3	-0.4	-0.2	-0.5	-0.5	-0.1
Wheat flour	0.0	-0.2	-0.1	-0.4	-0.5	-0.1
Maize	-0.2	-0.4	-0.3	1.5	0.5	0.9
Other staple food	-0.1	-0.8	-1.1	-0.5	-1.0	-1.1
Vegetable oil	-0.1	-0.3	-0.1	-0.4	-0.4	-0.1
Sugar	-0.1	-0.3	0.0	-0.4	-0.5	-0.1
Fruits	0.4	0.2	0.5	-0.4	-0.5	-0.1
Vegetables	0.9	0.6	0.9	-0.5	-0.5	-0.1
Ruminant meat	3.5	3.3	3.4	3.0	2.9	3.2
Pork	3.3	4.1	4.5	3.9	4.2	4.9
Poultry meat	2.5	3.3	4.6	2.6	3.6	5.0
Milk	3.9	4.2	5.4	3.5	3.9	5.2
Eggs	0.9	1.7	2.9	1.5	2.5	3.7
Fish	1.0	0.8	2.1	1.5	4.0	5.3
Total food	**1.7**	**2.2**	**2.8**	**2.1**	**2.9**	**3.8**

The growth rates of Table 4.14 do not cover the period 1997-2003. In general, as indicated already, the shifts in consumption pattern in this historical period were similar to the trends afterwards but we should mention also that detailed study of food consumption data over the historical period led to a considerable reduction in shares spent on wheat and rice from 1997 to 2003.

4.2 Scenario variants

As mentioned before, this report considers four scenario variants to the baseline. We discuss them by turns and at the end of the section highlight the main differences between them.

4.2.1 Liberalization scenario (LIBERAL)

The *liberalization* scenario uses the same demographic, economic growth, life style and technology change assumptions as the baseline. The same applies to land and water resources availability, i.e. the projections of cultivated land and irrigated land are the same in both scenarios. Only the agricultural price and border protection policies are changed. In addition to the WTO agreements of the baseline, the full liberalization scenario assumes a 50% elimination of border protection in 2010 from the 2003 levels, followed by full elimination between 2010 and 2020. Furthermore, the upper bound on vegetable exports increases with an additional one percent annually. International prices are the same as in the baseline. Hence, the additional liberalization measures are assumed to be unilateral, and the scenario abstracts from China’s impact on international prices.

4.2.2 High income growth scenario (HIGHGROW)

The *high income growth* scenario assumes faster GDP and income growth, driven by higher output of the non-agricultural sectors as compared to the baseline. By 2020 China's non-agricultural output will have risen to 3.5 times its size in 2003, and by 2030 it would reach 6.4 times this size, which amount to an average annual non-agricultural growth rate of 8.3% for the period 2003-2010, of 7.2% in the 2010s, and of 6.2% in the 2020s, compared to respectively 8.0%, 6.5% and 5.1% in the baseline. A substantial part of the additional non-agricultural output is exported, leading to a trade surplus rising at 12% annually, 2% above the baseline.

Higher economic growth is associated with faster urbanization, higher investment and higher public expenditures. The country's fixed investment and public consumption are now assumed to grow at annual rates of 8.3% and 5.6%, respectively, whereas by 2030 64% of the population will be urban. Higher economic growth and enhanced investment, jointly with more rapid urbanization, cause an additional 2 million hectares of farmland to be lost due to conversion into built-up areas. At the same time, the accelerated decline of the rural population leads to somewhat higher reduction in farm labor, resulting in 180 million manyears in 2030 as opposed to 189 million in the baseline. This is partly compensated by higher technical progress in agriculture with an additional 0.15% of output increasing technical progress in cropping and an additional 0.1% in livestock production annually.

Higher urbanization leads to more rapid changes in consumption pattern of migrants but also for those who remain within the same area, the better incomes raise food expenditures, especially on livestock products. This exogenous component of the adjustment operates via rural to urban migration as well as via an additional shift in budget shares, leading to uncommitted per capita food expenditure levels between 3 and 5% higher than in the baseline, with an additional upward shift for meat and milk.

Finally, population growth is a little higher in this scenario in response to income improvements, and total population reaches 1,462 million people by 2030, 3 million more than under the baseline.

4.2.3 High agricultural R&D investment scenario (TECHPROG)

The *high agricultural R&D investment* scenario assumes that additional policy efforts would be made to increase funding and investment in R&D for agriculture. This is supposed to lift technical progress in agriculture with an additional 0.2% of Solow-neutral productivity growth in annual cropping, and an extra 0.15% in pork and poultry production and the specialized dairy sector. Furthermore, the scenario assumes an annual improvement of fertilizer efficiency of 0.5%. Feed efficiency remains as in the baseline.

The assumptions build on Huang and Hu (2002) who estimate that China's internal rate of return on research in agriculture is 55 – 60% in terms of value added gain, only slightly lower than the average of 120 studies in Asia (67%), but higher than the world average (49%) reported in the comprehensive assessment by Evenson (2001). Nonetheless, in the scenario the increase is purely disembodied, and while not out of line from a historical perspective, the assumed growth rates neglect possible setbacks due to new animal and plant diseases, and are too general to have a direct link to ongoing research efforts. Rather this scenario is primarily intended to point to some of the bottlenecks that might be alleviated through effective research and development.

4.2.4 Enhanced irrigation development scenario (IRRIGUP)

In specifying the *enhanced irrigation* simulation experiment the aim is to investigate the impact of an assumed further irrigation expansion. The scenario uses the same demographic, economic and urbanization assumptions as the baseline. This also leads to the same trends in farmland conversion, i.e. a total land area of 116.6 million ha cultivated with seasonal crops in 2030. The main difference compared to the baseline is a gradual shift from rainfed to irrigated land that increases the country's effectively available irrigated land with 2.5% in 2010, 6.1% in 2020 and 10.0% in 2030, while orchard land is kept at baseline level. Then, by 2030, the irrigated land amounts to 61.5 million hectare, compared to 55.9 million hectare in the baseline.

The additional transformation of rainfed into irrigated land is regionally distributed building on a special study by Chen et al. (2005). Additions are largest in Northeast, North, Northwest and Central with 1.3, 1.1, 1.0 and 0.9 million ha, respectively, in 2030. In East, South and Southwest the additions are smaller (0.6, 0.3 and 0.4 million hectare, respectively) and in Plateau the difference is negligible.

Since irrigated land requires more labor and machinery per hectare, the scenario also assumes that government stimulates additional investments in machinery, as part of the enhanced irrigation program, and that increased labor requirements lead to a slightly lower decline of farm labor. Furthermore, the (exogenous) allocation of manure, animal draught power and machine power to rainfed and irrigated land is adjusted to the scenario shifts. These assumptions are implemented so as to keep average yields on irrigated and rainfed land close to their baseline level in each province. For the country as a whole, farm labor in 2030 is 0.5% higher than under the baseline, and farm machinery 7% higher.

We conclude this section by an overview of the main differences in the specification of the five scenario variants, at national level. They are summarized in Table 4.15.

Table 4.15 Key parameters underpinning the Chinagro scenarios at national level

Major driving forces	Scenarios				
	BASELINE	LIBERAL	HIGHGROW	TECHPROG	IRRIGUP
Non-agricultural output (index)					
2003	100	100	100	100	100
2010	172	172	175	172	172
2020	323	323	352	323	323
2030	533	533	642	533	533
Population (millions)					
2003	1301	1301	1301	1301	1301
2010	1362	1362	1362	1362	1362
2020	1429	1429	1431	1429	1429
2030	1459	1459	1462	1459	1459
Urbanization (%)					
2003	39	39	39	39	39
2010	44	44	45	44	44
2020	50	50	55	50	50
2030	58	58	64	58	58
Cropland with orchards (mill.ha)					
2003	136	136	136	136	136
2010	133	133	133	133	133
2020	131	131	130	131	131
2030	129	129	127	129	129
Irrigation share (%)					
2003	46.6	46.6	46.6	46.6	46.6
2010	46.6	46.6	46.6	46.6	47.8
2020	47.2	47.2	47.2	47.2	50.1
2030	47.9	47.9	47.8	47.9	52.7
Farm labor (million manyear)					
2003	245	245	245	245	245
2010	235	235	233	235	235
2020	219	219	212	219	219
2030	189	189	180	189	190
Import tariffs (index)*					
2003	100	100	100	100	100
2010	70 – 80	50	70 – 80	70 – 80	70 – 80
2020	60 – 70	0	60 – 70	60 – 70	60 – 70
2030	55 – 60	0	55 – 60	55 – 60	55 – 60
Export tariffs (index)					
2003	100	100	100	100	100
2010	75	50	75	75	75
2020	38	0	38	38	38
2030	38	0	38	38	38
Yearly neutral technical progress					
Cropping	0.20%	0.20%	0.35%	0.40%	0.20%
Livestock	0.80%	0.80%	0.90%	0.95%	0.80%

* In case of differences across commodities, the range is indicated.

5. Results of the baseline model simulation

Based on the scenarios described in the previous section, simulations were conducted with the Chinagro welfare model over a 30 year time horizon. The present section discusses the outcomes of the baseline scenario, reporting on: (1) production, consumption and trade at national level, (2) prices, (3) production, consumption and trade by region, (4) farm incomes and value added, and (5) environmental pressure. Outcomes of the scenario alternatives will be reported on in the next section. With respect to crops, the results are presented in terms of the Chinagro commodity classification, noting that they are also available at a more detailed level, viz. the 17 crops listed in Appendix A.

5.1 Food production, consumption and trade at national level

We discuss general tendencies before reporting on commodity-specific developments. Overall, the outcomes from the baseline show that China can produce most of its food domestically in the coming thirty years. However, with the fast growth of income and urbanization, it will have to import large amounts of animal feeds for its fast growing livestock herds, and eventually import white meat (pork and poultry).

Given China's relatively low labor cost and the ample farm population available to raise more livestock, given also the large scope for productivity improvements in livestock production as well as the relatively high cost of ocean transport of frozen meat, it seems efficient for China to make all efforts at producing its meat domestically. Yet, as decreasing returns in yield improvements eventually set in and urbanization proceeds, availability of farm-land will fall, labor cost will rise, and environmental pressures mount, reducing the room for expansion of stable capacity. Such considerations motivate the assumed general decline in the baseline growth rates of stable capacities in the intensified non-ruminant sector, specified earlier in Table 4.8, that trigger the growth in meat imports found in simulation.

In monetary terms, the meat and feed imports are projected to amount to 29 billion USD[18] in 2030. To a significant extent (10 billion USD) they are offset by exports of fruits and vegetables as well as rice. Revenues from net exports of fruits and vegetables have already been rising very steeply in recent years, reaching 2.5 and 3.3 billion USD in 2003 and 2004, respectively (NBSCa, 2005). Imports of milk (6 billion USD) and other food crops, mainly vegetable oils and sugar (7 billion USD) will also rise. In all, our model simulations suggest that in 2030 China will have an agricultural trade deficit of 29 billion USD. Hence, as China's trade surplus in non-agriculture already exceeds 100 billion USD in 2005 (NBSCa, 2006), it would under the assumed trends in non-agriculture not be difficult to finance the agricultural trade deficit in 2030.

The demand system postulated in the model assumes that per capita consumption of food grains will decrease with income and even more so with migration to urban areas, while demand for livestock products will increase. The baseline outcomes reflect these trends, in particular the major impact of rural-to-urban migration on the resulting averages. For example, from 1997 to 2030, per capita demand of rice declines slightly for both rural and urban households, but because of urbanization, the national average per capita demand of rice drops from 96.7 kg to 87.3 kg in 2030. In certain regions or periods such per capita declines even lead to declining absolute grain consumption levels, as will be seen below. Per capita demand of other food crops will

[18] Throughout, USD refers to US dollars of 1997.

approximately keep their current levels or increase modestly. For livestock products the demand pressures are so high that even considerable price increases cannot forestall high growth in per capita consumption.

Turning to commodity-specific developments (shown in Table 5.1 for food crops, Table 5.2 for livestock products and Table 5.4 for feed, with in Table 5.3 more detail on consumption) and focusing on the period 2003-2030, we note the following.

Rice. Initial self-sufficiency turns into moderate exports (4 million ton) from 2020 onwards. We recall from the scenario description that in 2003 exports were related to stock disposal, whereas production was at its lowest level since years.[19] Given the current world market trade in rice of close to 30 million ton, the export levels in 2020 and 2030 do not seem excessive. Per capita consumption declines from 95.2 kg at present to 87.3 kg, largely due to urbanization. That exports do not rise faster, given this drop in per capita demand, the ongoing technological progress and new developments of irrigation is due to modest but steady population growth, and the loss of irrigated land to urbanization.

Wheat. The trends generated are similar to those of rice: production in 2003 is at its lowest level since years, exports in 2003 are due to stock disposal and the market turns into self-sufficiency afterwards, while per capita consumption declines from 61.8 to 55.7 kg. The drivers behind these trends are similar as well: population growth and loss of land to urbanization compensate for demand satiation and technological progress. However, unlike rice, wheat does not end up in an export regime.

Vegetable oils and sugar. There are steady increases of import volumes, leading to 9.1 million ton oil imports and 3.1 million ton sugar imports in 2030. Production of vegetable oil stagnates, and even declines somewhat, due to unfavourable prices. Per capita consumption of oil remains almost constant at about 9.5 kg, while sugar consumption increases modestly from 7.1 to 8.4 kg because of rise in income and urbanization. Clearly, this increase in imports assumes unchanged policies, in particular regarding the development of new sugar refineries in the South. For reference, current world trade levels are around 42 million tons of sugar (refined-equivalent) and 60 million tons oils (incl. animal fats).

Fruits and vegetables. Exports of fruits grow steadily from 2.3 million ton in 2003 to 4.7 million ton in 2030 while per capita consumption increases modestly, from 45 to 48 kg. Similarly, vegetable exports rise from 4.6 million ton in 2003 to 13.3 million ton in 2030, while per capita consumption declines slightly from the 2003 level of 165 to 163 kg, which is still high by international standards. The baseline scenario imposes an upper bound on these exports that increases from 5.3 to 15.4 million ton, as this volume is high relative to the current world exports of about 50 million ton according to FAO.

Meat. Per capita consumption rises from 3.5, 26.1 and 6.3 kg in 2003 for ruminant meat, pork and poultry meat to 5.6, 40.1 and 11.8 kg, respectively, in 2030. Until 2010 China can maintain self-sufficiency in meat but beyond that year it will import some poultry (4% of consumption). After 2020 imports accelerate, reaching 16 percent of poultry consumption and 10 percent of pork consumption, mainly because the stable capacities grow less than demand. Self-sufficiency is

[19] We note, however, that, the baseyear (1997) production levels for rice and wheat are both at an all-time high.

maintained in ruminant meat and eggs throughout the next thirty years.[20] Nonetheless, with 9.1 million ton altogether, the meat import flows will be considerable relative to the current level of world trade in meat of about 25 million ton.

Table 5.1 Supply, demand, net outflow and self-sufficiency rate of major food crops for China under baseline (million tons)

	1997	2003	2010	2020	2030
Supply					
Rice (milled)	124.7	111.7	129.8	136.5	136.0
Wheat flour	80.6	68.3	83.5	85.2	84.1
Vegetable oil	8.7	10.6	9.8	10.1	10.2
Sugar	7.3	8.4	9.0	9.5	9.5
Fruit	54.0	63.2	69.2	74.7	78.3
Vegetables	216.4	244.0	253.7	268.3	278.7
Demand					
Rice (milled)	124.0	127.7	129.8	132.1	131.7
Wheat flour	81.4	82.9	83.4	85.2	84.1
Vegetable oil	11.0	15.3	16.6	18.3	19.4
Sugar	7.7	9.7	10.7	11.7	12.6
Fruit	53.8	60.9	65.2	70.8	73.6
Vegetables	214.7	239.4	246.1	260.5	265.4
Net outflow					
Rice (milled)	0.7	1.5	0.0	4.4	4.3
Wheat flour	-0.9	1.9	0.1	0.0	0.0
Vegetable oil	-2.3	-4.7	-6.8	-8.2	-9.1
Sugar	-0.4	-1.3	-1.7	-2.2	-3.1
Fruit	0.2	2.3	4.0	3.8	4.7
Vegetables	1.8	4.6	7.6	7.8	13.3
Self-sufficiency rate (%)					
Rice (milled)	101	101	100	103	103
Wheat flour	99	103	100	100	100
Vegetable oil	79	69	59	55	53
Sugar	95	87	84	81	75
Fruit	100	104	106	105	106
Vegetables	101	102	103	103	105

Note. In 2003 the net outflow of wheat and rice is not equal to supply minus demand since stock decreases of 17.5 and 16.5 million ton, respectively, are omitted from the table.

[20] The existence of trade and transportation costs and tariffs results for each of the (homogeneous) commodities in a domestic price range in which neither imports nor exports are profitable. Hence, the relatively high frequency of self-sufficiency rates of 100.

Table 5.2 Supply, demand, net outflow and self-sufficiency rate of livestock products for China under baseline (million tons)

	1997	2003	2010	2020	2030
Supply					
Beef and mutton	4.6	5.0	6.0	7.4	8.5
Pork	28.7	34.7	40.9	49.0	53.3
Poultry meat	6.5	8.2	10.2	12.6	14.6
Milk	10.0	13.7	18.8	24.5	28.7
Egg	12.7	16.2	20.3	25.4	29.2
Demand					
Beef and mutton	4.5	5.0	6.0	7.4	8.5
Pork	28.4	34.7	40.9	49.0	59.5
Poultry meat	6.3	8.2	10.2	13.2	17.5
Milk	10.0	15.6	22.7	36.6	57.6
Egg	12.7	16.2	20.3	24.6	29.2
Net outflow					
Beef and mutton	0.1	0.0	0.0	0.0	0.0
Pork	0.3	0.0	0.0	0.0	-6.2
Poultry meat	0.2	0.0	0.0	-0.6	-2.9
Milk	0.0	-1.9	-3.9	-12.1	-28.9
Egg	0.0	0.0	0.0	0.8	0.0
Self-sufficiency rate (%)					
Beef and mutton	102	100	100	100	100
Pork	101	100	100	100	90
Poultry meat	103	100	100	96	84
Milk	100	88	83	67	50
Egg	100	100	100	103	100

Milk. Per capita consumption increases from 11.6 kg in 2003 to 38.7 kg in 2030. Domestic supply cannot follow that pace, basically because the scenario assumptions are rather moderate for the specialized dairy sector,[21] which also starts from a very low base. By 2030 imports of 28.9 million ton of milk equivalent cover half of consumption, which is significant given the fact that world trade in dairy currently reaches around 90 million ton in whole, fresh milk equivalent.

Eggs. Per capita consumption rises from 12.0 kg in 2003 to 19.5 kg in 2030, a considerable increase that can, however, be met from domestic supply. Hence, the country remains in self-sufficiency, and even has some exports in 2020.

Fish. Production is purely scenario driven and grows steadily, while consumption keeps on rising at about 2.5 percent annually, which amounts to a per capita consumption increasing from 15.5 kg in 2003 to 27.7 kg in 2030. Exports are fully exogenous and assumed to grow from 1.4 to 1.6 million ton.

[21] Compared e.g. to Fuller et al. (2006).

Table 5.3 Per capita consumption of main agricultural products in China, rural and urban (kg/person/year)

	Rural					Urban					National				
	1997	2003	2010	2020	2030	1997	2003	2010	2020	2030	1997	2003	2010	2020	2030
Milled rice	107.3	107.9	106.1	105.0	105.3	76.2	75.2	74.6	74.1	74.0	96.7	95.2	92.3	89.5	87.3
Wheat flour	70.6	71.7	70.2	70.3	70.7	47.2	46.3	45.5	45.2	44.7	62.6	61.8	59.3	57.8	55.7
Maize	16.1	17.3	17.0	16.7	16.4	7.4	8.1	8.2	8.4	8.6	13.2	13.7	13.2	12.5	11.9
Other staple food	14.4	15.6	15.5	15.3	15.1	20.5	22.4	22.1	21.5	20.6	16.4	18.2	18.4	18.4	18.3
Vegetable oil	8.7	10.3	10.5	10.5	10.5	8.0	8.4	8.5	8.4	8.3	8.5	9.6	9.6	9.5	9.2
Sugar	3.5	4.3	4.4	4.3	4.4	9.9	11.6	11.7	11.6	11.4	5.7	7.1	7.6	8.0	8.4
Fruits	29.6	31.2	30.4	30.9	30.6	65.6	66.9	65.2	63.8	61.1	41.9	45.1	45.7	47.4	48.2
Vegetables	138.9	152.2	149.6	152.4	153.3	177.8	185.6	180.7	176.6	170.6	152.1	165.2	163.2	164.5	163.3
Ruminant meat	1.3	1.3	1.5	1.7	1.8	7.1	7.1	7.6	8.3	8.5	3.3	3.5	4.2	5.0	5.6
Pork	16.5	19.4	21.2	23.4	27.3	33.6	36.8	39.8	43.7	49.6	22.3	26.1	29.4	33.6	40.1
Poultry meat	3.0	3.5	3.9	4.4	5.4	9.4	10.6	11.8	13.7	16.5	5.2	6.3	7.4	9.1	11.8
Milk	0.9	2.0	2.9	4.7	7.3	20.9	26.7	33.1	45.3	61.9	7.7	11.6	16.1	25.0	38.7
Eggs	5.9	7.2	8.2	8.9	9.5	17.4	19.7	22.2	24.6	26.8	9.8	12.0	14.4	16.7	19.5
Fish	7.2	7.3	7.3	7.5	7.7	26.9	28.6	31.2	36.3	42.5	13.9	15.5	17.8	21.9	27.7

Table 5.4 Supply, demand, net outflow and self-sufficiency rate of tradable feeds for China under baseline

	1997	2003	2010	2020	2030
Supply					
Maize	98.8	107.1	113.1	118.9	118.8
Carbohydrate feed	303.5	305.6	297.8	289.8	275.8
Protein feed	191.9	190.8	203.7	212.3	213.4
Demand					
Maize, food	16.9	18.4	18.4	18.3	17.8
Maize, feed	81.7	95.2	108.0	120.6	123.0
Carbohydrate feed	304.2	327.3	336.6	348.3	332.5
Protein feed	205.3	251.0	284.4	320.1	327.0
Net outflow					
Maize	6.4	13.4	-13.4	-20.1	-22.0
Carbohydrate feed	-0.7	-21.6	-38.8	-58.5	-56.7
Protein feed	-13.4	-60.2	-80.7	-107.8	-113.6
Self-sufficiency rate (%)					
Maize	107	114	89	86	84
Carbohydrate feed	100	93	88	83	83
Protein feed	93	76	72	66	65

Notes: - maize volumes are expressed in million tons, carbohydrate feed and protein feeds in million Gcal,
- for maize the 1997 and 2003 stock decreases of 6.2 and 20.0 million ton are omitted from the table.

Animal feeds (maize, carbohydrate feeds and protein feeds). Supplies of maize and protein feeds grow at an average modest rate of 0.4% in the period 2003-2030. This is less than the growth rate of the main staples wheat and rice, basically because the latter had to recover from a serious production dip in 2003. For carbohydrate feed the situation is different since its supply appears to decline, due partly to a weak performance of root crops (in response to price reductions) and partly to the tighter sanitary measures assumed in the baseline that reduce the possibilities of using household waste and crop residuals as feed. In contrast, feed demand keeps on rising, especially the demand for protein feeds from the intensified livestock sectors. At the same time, it precisely is this transition to intensified production that keeps the growth of total feed demand limited, through the higher feed efficiency as compared to the traditional sectors. It also appears that in absolute amounts the role of local feeds is not diminishing. We will expand on this in subsection 5.4.

Consequently, feed imports rise steadily but the volumes do not become excessive. By 2030, for maize, 16 percent of domestic use is imported, for carbohydrate feeds 17 percent and for protein feeds 35 percent. Converting the carbohydrate quantities into grain equivalent through division by a factor 3.4 mcal/kg (see appendix A), gives an import of 16.7 million ton grain equivalent in 2030. Similarly, for a factor of 3 mcal/kg the 2030 imports of protein feed can be expressed as an import volume of 37.8 million ton of cake/bran equivalent. For reference, current world trade levels of maize are around 90 million ton, other coarse grains around 15 million ton, bran around 5 million ton and soybean cake around 50 million tons, whereas world trade in wheat reaches around 120 million ton (food plus feed). We note that wheat used as animal feed could be considered part of carbohydrates and protein feeds, since it substitutes for these. In all, the imports of animal feeds are spectacular, not so much from the perspective of China itself that can easily cover them from exports but purely as a strain on the world market.

These commodity-specific outcomes confirm that for non-feed crops self-sufficiency is largely preserved, which is especially significant for rice and wheat, the two dominant food grains in the country. Self-sufficiency in these two commodities has long been seen as major yardstick of the country's food security. After 2020, rice will even be exported, although one may, given the thinness of the world rice market, put to question that this would be possible without causing the international price to fall, as was assumed in this scenario. In addition, China will also export significant volumes of fruits and vegetables while importing oils and sugar. This comfortable situation for non-feed crops is mainly because technical progress in agriculture and higher input intensity more than compensate for the reduction in total land area available, and because the drop in per capita food-grain consumption with rising income and urbanization, is stronger than the increase in demand due to the, modest, overall rise in population.

As China's integration into the world market becomes deeper, its strength in exporting labor intensive products will become more evident, while land-intensive products will lose. Hence, an orientation on livestock and horticulture would seem natural. Yet, it appears that the country will have to import livestock products towards the end of the period, and also that the imports of feed grains are quite high from the perspective of the world market, especially if one takes into account that the baseline scenario keeps world market prices fixed at scenario values and disregards any "new" demands for biofuels from agriculture by China as well as by other countries.

5.2 Prices

Domestic prices of main products in the crop sector will more or less follow the same pattern of recovery after 2003 as the world market prices in the scenario specification that mainly reflects the upcoming demand for livestock products in Asia while disregarding future growth in demand for biofuels. The recovery is assumed to last until 2020, and followed by a period of slight reduction in world prices. Yet, the domestic pattern is not exactly the same for each crop due to decreasing tariff rates, decreasing trade and transport margins and switches of trade regime (import, export, self-sufficiency). Below, we will discuss it crop by crop. By contrast, beef and mutton, pork, and poultry meat that face high trade and transport margins on import and start from autarky, will witness a steady price increase, significantly above the world price scenario.

The market clearing prices are listed in Tables 5.5 and 5.6 for crops and livestock products, respectively. They appear by region, since the Chinagro model operates with regional markets and has no national market.[22] Clearly, prices are determined simultaneously with supply and demand, as in any equilibrium model. Farmgate prices do not appear in the table. They are calculated by county and differ from the regional market prices due to processing (including trade and transport) and domestic producer taxes. In our discussion of farm value added below we comment on notable price developments at county level. Consumer prices are computed as the regional market price plus consumer tax and processing margin, specific for each rural and urban income group, and are not discussed separately.

[22] The national market balances of the previous subsection are obtained by summation of the regional market balances.

Table 5.5 Regional market price of main crop products under baseline (Yuan/kg)

		North	Northeast	East	Central	South	Southwest	Plateau	Northwest
Rice	1997	2.34	2.02	1.93	1.77	2.29	2.20	2.39	2.28
	2003	1.94	1.62	1.54	1.37	1.89	1.80	1.99	1.88
	2010	2.06	1.75	1.66	1.50	2.02	1.93	2.12	2.01
	2020	2.12	1.80	1.72	1.55	2.07	1.98	2.17	2.06
	2030	1.96	1.65	1.56	1.40	1.92	1.83	2.02	1.91
Wheat	1997	1.62	1.63	1.53	1.57	1.79	1.64	1.76	1.65
	2003	1.23	1.24	1.14	1.18	1.40	1.25	1.37	1.26
	2010	1.38	1.40	1.29	1.33	1.55	1.40	1.53	1.41
	2020	1.33	1.35	1.25	1.29	1.51	1.36	1.48	1.36
	2030	1.23	1.25	1.15	1.18	1.40	1.25	1.38	1.26
Maize	1997	1.11	1.18	1.19	1.21	1.20	1.18	1.20	1.16
	2003	0.99	1.06	1.07	1.09	1.08	1.06	1.08	1.04
	2010	1.05	1.12	1.13	1.15	1.14	1.12	1.14	1.10
	2020	1.09	1.15	1.16	1.18	1.17	1.15	1.17	1.13
	2030	1.04	1.10	1.11	1.13	1.12	1.10	1.12	1.08
Vegetable oil	1997	7.40	7.30	7.36	7.39	8.23	7.39	7.36	7.34
	2003	5.74	5.64	5.71	5.74	6.58	5.74	5.71	5.69
	2010	5.44	5.34	5.40	5.44	6.25	5.43	5.41	5.39
	2020	5.23	5.14	5.20	5.23	6.00	5.23	5.21	5.19
	2030	4.89	4.80	4.86	4.89	5.62	4.89	4.87	4.85
Sugar	1997	3.84	3.73	3.86	3.85	3.84	3.82	3.97	3.83
	2003	2.79	2.68	2.81	2.80	2.79	2.77	2.91	2.77
	2010	2.71	2.60	2.73	2.72	2.70	2.69	2.83	2.69
	2020	2.72	2.62	2.75	2.74	2.72	2.70	2.85	2.71
	2030	2.54	2.44	2.56	2.55	2.54	2.52	2.66	2.52
Fruits	1997	1.24	1.46	1.54	1.48	1.36	1.51	1.51	1.08
	2003	1.36	1.58	1.66	1.60	1.48	1.63	1.63	1.20
	2010	1.51	1.73	1.80	1.74	1.62	1.77	1.78	1.34
	2020	1.52	1.74	1.82	1.76	1.64	1.79	1.79	1.36
	2030	1.54	1.76	1.84	1.78	1.66	1.81	1.81	1.38
Vegetables	1997	0.87	1.04	0.78	0.71	0.87	0.99	0.96	0.90
	2003	0.80	0.96	0.71	0.64	0.79	0.92	0.88	0.83
	2010	0.94	1.10	0.84	0.77	0.93	1.05	1.02	0.97
	2020	0.99	1.15	0.89	0.82	0.98	1.10	1.07	1.02
	2030	1.04	1.14	0.94	0.87	1.02	1.10	1.12	1.06

Table 5.6 Regional market price of main livestock products under baseline (Yuan/kg)

		North	Northeast	East	Central	South	Southwest	Plateau	Northwest
Beef and mutton	1997	10.45	9.59	10.97	9.87	10.68	9.42	8.19	9.53
	2003	15.14	14.28	15.66	14.56	15.37	14.11	12.88	14.21
	2010	15.39	14.53	15.91	14.81	15.61	14.36	13.13	14.46
	2020	17.45	16.59	17.96	16.87	17.67	16.42	15.19	16.52
	2030	21.44	20.58	21.96	20.86	21.67	20.41	19.18	20.52
Pork	1997	11.03	10.00	12.14	10.60	12.67	9.77	10.13	9.58
	2003	12.75	11.69	13.86	12.32	14.47	11.49	11.82	11.29
	2010	14.78	13.72	15.88	14.35	16.51	13.52	13.85	13.32
	2020	19.02	17.96	20.13	18.59	20.74	17.76	18.09	17.56
	2030	21.81	20.91	22.62	21.39	22.09	21.14	21.04	21.34
Poultry meat	1997	10.75	11.41	13.18	12.84	16.79	15.77	14.59	11.83
	2003	12.28	12.95	14.72	14.38	18.32	17.30	16.13	13.37
	2010	14.16	14.83	16.59	16.26	20.19	19.18	18.00	15.25
	2020	18.06	18.73	20.50	20.16	21.70	20.68	21.90	19.15
	2030	20.43	21.09	22.86	22.52	20.74	21.80	23.05	21.51
Milk	1997	3.08	2.67	2.97	2.85	2.76	2.73	2.79	2.53
	2003	3.09	2.68	2.98	2.86	2.77	2.74	2.80	2.54
	2010	2.82	2.41	2.71	2.60	2.51	2.48	2.54	2.27
	2020	2.63	2.24	2.53	2.43	2.34	2.31	2.35	2.10
	2030	2.46	2.10	2.36	2.27	2.18	2.21	2.18	2.00
Egg	1997	5.52	5.87	6.33	7.39	8.20	7.61	6.44	5.80
	2003	5.23	5.58	6.04	7.10	7.91	7.32	6.15	5.51
	2010	4.85	5.20	5.66	6.72	7.53	6.94	5.77	5.14
	2020	5.44	5.78	6.24	7.31	8.11	7.52	6.35	5.72
	2030	5.91	6.26	6.72	7.78	8.59	8.00	6.83	6.20

Note: The 1997 beef and mutton prices appearing in the table are too low, due to statistical problems that no longer exist in 2003. Hence, the price rise from 1997 to 2003 is to some extent an artefact.

We may recall from section 3 that all prices are "real" and, through deflation of the non-agricultural price, comparable to the 1997 level. As the differences between regions are small, we focus on average trends over regions. In fact, regional differences mainly arise when a region changes its trade regime, such as Southwest where in 2030 the continuing increase in vegetable output leads to a lower price relative to other regions, as can be seen in Table 5.5, allowing exports to some of these regions. We also focus our discussion on the period 2003-2030, hence disregarding the price fall experienced by most crops between 1997 and 2003 and starting, therefore, at relatively low crop prices.

Rice prices end up slightly higher in 2030 as compared to 2003. However, they are lower than if they purely followed the world price. The main reason for the difference is the transition to an export regime that reduces the domestic prices. Although this negatively impacts on domestic supply, production levels remain sufficiently high to maintain positive exports.

W*heat* prices in 2030 are about as high as in 2003. They do not follow the fall in the world price because wheat operates in a self-sufficiency regime, which implies that domestic supply and demand drive price formation. It appears that demand is strong enough to keep prices above the level where export becomes profitable.

Maize prices in 2030 are about 4% higher than in 2003. Maize remains in import regime, implying that the domestic prices are equal to the foreign price incremented by import tariffs and the trade and transport margin on imports. Since both the import tariff rates and the import margin are gradually being reduced, the domestic price increases less than the foreign price which ends up in 2030 10% higher than in 2003. *Other feeds* are not mentioned in the table but their price patterns are similar to those of maize.

Vegetable oil and *sugar* are both imported in all years. Therefore, they follow the same pattern as maize, with their prices dropping more than the world price, and by 2030 end up about 15% and 9% below their 2003 level, respectively. For *fruits* and *vegetables* the pattern is different, since these commodities are exported and the gradual decrease in their export tariff and export trade and transport margins raises domestic prices, leading to steadily rising prices. For vegetables, this trend is maintained despite the upper bound on exports that becomes active in 2030 in some regions, thereby depressing the domestic price.

Developments in meat prices (*beef and mutton, pork, poultry meat*) were already discussed above. Prices rise significantly as demand grows faster than domestic supply, causing transition to an import regime. For example, the price of pork in 2003 is about 12 Yuan/kg and it will almost double relative to 2003 reaching 22 Yuan/kg by 2030.

For *milk*, which remains in import regime throughout the baseline simulation, the domestic prices fall steadily, say, from 2.9 to 2.4 Yuan/kg. This decline is the combined outcome of three effects, a falling world price, a reduced import tariff rate and a lower trade and transport margin on imports.

Finally, *egg* prices are increasing steadily. By 2030 they are about 12% higher than in 2003. Since eggs are largely in the self-sufficiency regime, this outcome results from domestic market clearing with a gradually stronger demand pressure.

5.3 Food production, consumption and trade by region

We now present the regional commodity balances that correspond to the national balances of subsection 5.1. Obviously, the main national trends also show up at regional level. Therefore, we only mention relative differences across the regions.

Table 5.7 Per capita consumption of grain and meat in different regions under baseline (kg/caput)

	Grain					Meat and egg				
	1997	2003	2010	2020	2030	1997	2003	2010	2020	2030
Rural consumer										
North	195.3	199.0	196.0	196.7	197.7	24.7	29.5	33.6	37.4	42.5
Northeast	176.7	183.4	180.4	180.1	182.3	27.9	33.2	37.4	41.5	47.4
East	202.4	205.4	202.5	202.4	204.7	30.1	35.3	39.7	44.8	52.7
Central	204.9	208.1	204.4	202.3	203.4	25.6	29.8	32.7	35.8	40.8
South	204.7	205.3	203.1	201.7	202.3	31.1	36.3	40.1	45.8	56.3
Southwest	190.9	192.1	187.1	182.4	180.7	29.7	34.7	37.2	39.0	41.9
Plateau	142.3	141.9	137.6	134.9	132.1	17.1	17.6	19.5	20.6	20.7
Northwest	169.6	172.9	169.1	168.7	168.4	16.6	19.7	22.5	25.1	27.9
Urban consumer										
North	130.2	129.6	128.3	128.0	127.6	70.5	78.2	86.9	96.3	107.6
Northeast	131.4	130.7	129.3	128.7	128.2	59.9	66.1	73.5	81.1	89.7
East	135.4	133.4	131.3	129.7	128.4	74.1	81.3	88.6	97.0	107.0
Central	124.6	123.2	121.6	120.3	119.6	60.5	67.0	73.9	82.1	92.1
South	137.7	136.1	135.6	135.4	135.2	66.6	72.3	78.7	88.5	103.5
Southwest	117.2	116.4	115.4	115.1	114.9	76.0	82.4	88.9	97.4	108.0
Plateau	141.2	140.9	140.3	140.6	140.8	63.0	68.8	76.3	85.6	97.0
Northwest	133.8	132.8	131.2	130.7	130.1	55.2	60.8	68.0	75.8	83.6
Total population										
North	175.1	174.1	168.0	163.9	158.8	38.9	46.9	55.6	65.5	78.6
Northeast	154.4	155.1	151.1	148.4	145.9	43.7	50.9	58.1	65.9	75.8
East	175.6	173.0	166.6	161.1	155.8	47.7	56.0	64.4	74.4	87.5
Central	181.1	179.1	171.9	165.1	159.2	36.0	42.5	48.9	56.8	67.8
South	176.6	172.7	167.5	162.7	158.0	46.0	53.3	60.4	70.9	87.5
Southwest	173.2	170.8	163.6	156.2	150.0	40.8	48.1	54.1	61.7	72.7
Plateau	142.0	141.6	138.5	137.1	136.1	28.5	32.4	38.3	45.6	55.5
Northwest	158.8	159.1	154.4	151.7	148.5	28.2	33.8	40.2	47.7	56.8

It appears that for many commodities the distribution of production across regions remains remarkably stable, despite the significant changes in farm population and in land availability in the scenario, and the marked shifts in overall output composition in every region. The changes in the net trading position of the regions largely originate from the demand side, driven by income changes and migration, with price adjustments (discussed in the previous subsection) as mitigating factors. The resulting fast rising internal trade flows place significant demands on domestic trade and transport infrastructure.

Table 5.7 shows the development of per capita demand in each region, as well as the separate figures for urban and rural consumers.[23] For grain, one may observe a slight drop in per capita demand in both rural and urban regions. Total per capita demand drops faster in all regions, due to urbanization. For meat the individual trend and the urbanization effect are mutually reinforcing, leading to significant per capita increases at regional level. Trends in per capita demand are rather similar across the regions. Per capita meat demand in 2030 (including eggs) is in all regions 1.5 to 1.7 times higher than in 2003. Per capita grain demand falls everywhere, ending up 6% to 12% below the 2003 level, with the highest fall in Southwest and Central regions, where urbanization is fast and urban grain intake relatively low.

The effect of interregional migration and natural population growth on demand is better captured in Tables 5.8 and 5.9 with absolute demand volumes. Although population continues to grow in all regions, the rate of growth is not always sufficient to compensate for per capita declines in demand. Therefore, significant differences show up across regions. For rice and wheat, demand rises in some regions and falls in others. Rice consumption decreases in Northeast, Central and Southwest, whereas wheat consumption decreases in Northeast and also, despite net immigration from other regions, in North and East. Naturally, the absolute levels of meat demand increase everywhere at a higher rate than the per capita intake mentioned above. It almost doubles in North and even more than doubles in South.

Turning to the supply side, we remark that the regional volumes as shown for 2003 and 2030 in Tables 5.8 through 5.10 are actually derived as aggregates of county-specific outcomes. As mentioned earlier, the regional distribution is rather stable over time for many commodities but there are a few exceptions to this general trend, which we discuss here. Supply increases of rice are higher in Northeast, Central and Southwest than elsewhere. The acceleration in Northeast is clearly the result of the enlargement of its irrigated area. The large rice producers Central and Southwest do not have this advantage, as none of the other regions, but their loss of irrigated area is relatively small and dominated by the benefits of technical progress. In the two other important rice producing regions, East and South, the loss of irrigated land goes faster, although also here a production increase results. For fruits, supply is stagnating in South due to the decline of orchard land, whereas it is growing elsewhere. For vegetables, we see stagnation in East where it is the main crop and has a relatively high farmgate price, due to favorable crop composition. Consequently, a given absolute rise in price means less percentage-wise for this region, that also suffers from a loss of irrigated and rainfed land, especially in the counties close to urban areas where vegetable production is most intense. The rates of growth in meat and milk production largely follow those of stable capacities that vary across regions. This explains that meat increases are largest in South, with about a doubling of output between 2003 and 2030, and that milk increases are largest in North, Northwest and Plateau, where output in 2030 is more than 2.5 times as high as in 2003. By contrast, feed supply increases at a rate that is remarkably uniform across regions.

[23] Actually, the Chinagro model operates at a lower level of detail, viz. with three urban and three rural classes by region.

Table 5.8 Regional supply, demand, and net outflow of main food crop products under baserun (1000 tons)

	Rice		Wheat		Vegetable oil		Sugar		Fruit		Vegetable	
	2003	**2030**	**2003**	**2030**	**2003**	**2030**	**2003**	**2030**	**2003**	**2030**	**2003**	**2030**
Supply												
North	3550	4120	36721	44151	2847	2669	69	79	23154	30120	71516	81720
Northeast	9442	13970	1855	2401	960	896	393	430	3796	4465	21745	24392
East	25698	28863	11060	13246	1973	1818	107	105	5729	6387	37544	38022
Central	32396	40341	2442	3209	1960	1960	489	515	4739	5640	36032	42082
South	20875	23649	151	166	519	537	5098	5496	13101	13249	29792	33736
Southwest	18239	23123	5697	7458	980	979	1556	1964	4160	5403	32079	39357
Plateau	3	4	616	758	81	80	0	0	23	24	481	580
Northwest	1486	1921	9727	12746	1243	1298	695	876	8492	13009	14795	18804
Demand												
North	6873	8701	43395	41940	3652	4552	2060	2744	18389	23181	67740	74395
Northeast	9160	8627	4502	4473	1341	1486	548	569	6251	6246	26089	25755
East	24952	24415	9954	9487	3149	4214	2106	2470	12381	13642	32003	33761
Central	28197	25320	2590	2823	2314	2442	1059	1276	6949	7450	29263	30515
South	29124	37171	2479	4169	1928	3378	1961	2914	6229	9327	29726	40117
Southwest	26293	23390	4996	5073	1692	1765	1341	1716	5325	6858	36479	37994
Plateau	138	194	1032	1289	71	92	44	70	308	449	1189	1577
Northwest	2951	3920	13969	14879	1137	1456	599	836	5067	6473	16924	21303
Net outflow												
North	-2776	-4581	1980	2211	-805	-1883	-1991	-2665	4765	6939	3776	7324
Northeast	1697	5343	-2115	-2072	-382	-589	-155	-139	-2455	-1781	-4345	-1363
East	4778	4448	3932	3759	-1176	-2395	-1999	-2365	-6653	-7255	5540	4260
Central	9387	15021	504	386	-354	-482	-571	-761	-2210	-1809	6769	11567
South	-4972	-13521	-2290	-4003	-1409	-2841	3138	2581	6872	3922	66	-6380
Southwest	-5261	-267	2056	2384	-712	-786	215	248	-1165	-1455	-4400	1363
Plateau	-135	-190	-274	-531	10	-12	-44	-70	-285	-425	-708	-997
Northwest	-1217	-1999	-1941	-2133	107	-158	95	40	3425	6536	-2129	-2498

Note. In 2003 the net outflow of wheat and rice is not equal to supply minus demand since the stock decreases are omitted from the table, as in table 5.1.

Table 5.9 Regional supply, demand, and net outflow of main livestock products under base scenario (1000 tons)

	Beef and mutton		Pork		Poultry meat		Milk		Egg	
	2003	2030	2003	2030	2003	2030	2003	2030	2003	2030
Supply										
North	1635	2838	6416	9330	2131	3409	3673	8745	6862	11782
Northeast	572	819	2555	3905	1193	1858	2306	3982	2161	3462
East	377	533	4501	6524	1449	2074	1074	1925	2581	4267
Central	303	343	6459	9682	532	1039	568	587	1052	2106
South	192	227	4990	10045	1632	3963	823	964	1031	2870
Southwest	432	618	7749	10342	1037	1864	1320	2215	1465	2676
Plateau	250	636	80	138	2	2	761	2123	19	62
Northwest	1210	2515	1968	3369	193	386	3132	8170	1039	1951
Demand										
North	1322	2281	6585	11997	1594	3345	4115	16989	5871	10412
Northeast	772	1108	2470	3584	527	834	1713	5150	1867	2754
East	620	987	5947	9885	1870	3292	4164	13653	3045	5011
Central	389	660	4587	7014	818	1439	879	3028	1602	2852
South	494	1107	5817	12875	2082	5735	1236	5322	1569	3710
Southwest	391	639	7355	10535	929	1991	1188	4076	1228	2163
Plateau	124	207	112	266	9	26	428	1414	39	116
Northwest	860	1539	1845	3369	340	798	1876	7982	988	2159
Net outflow										
North	313	557	-169	-2667	537	65	-442	-8244	991	1371
Northeast	-200	-289	85	321	666	1024	594	-1168	294	707
East	-243	-454	-1446	-3362	-421	-1218	-3090	-11727	-464	-744
Central	-86	-317	1872	2667	-285	-400	-311	-2441	-550	-745
South	-302	-881	-827	-2830	-450	-1772	-413	-4358	-538	-840
Southwest	42	-21	395	-193	108	-126	131	-1862	237	513
Plateau	126	429	-32	-128	-7	-23	333	709	-20	-54
Northwest	351	976	123	0	-147	-412	1255	189	51	-207

After combining demand and supply sides, one obtains the net trade positions of the regions. With respect to specific crop production, calculated by summation over counties, we see in Table 5.8 that by 2030 the geographic specialization in *rice* and *wheat* production will continue to make the Central, Northeast and East regions be the leading sellers of rice and East, Southwest, and North the leading sellers of wheat. On the buying side, the current number one buyer for rice, the Southwest, will likely become close to self-sufficient in rice, while South, the most industrialized region, would become number one buyer for rice and remain number one buyer for wheat. North, the main wheat region, with about half of the country's supply and demand, remains a modest net seller.

For *vegetable oil* and *sugar*, demand increases faster than supply, largely since prices become unfavorable relative to other crops (as was seen in Table 5.5). All regions remain or become net buyers of vegetable oil, whereas for sugar South remains a large seller while Southwest and Northwest manage to keep a supply surplus, albeit of modest size.

The present leading position of South as seller of *fruit* will likely be overtaken by North and Northwest, for reasons discussed earlier. The current top three buyers, East, Northeast and Central, keep their position. For *vegetables*, the Central, North and East will continue to be leading sellers, with East losing dominance, due to stagnation of its production. Southwest also becomes a net seller but South, the most industrialized region, will give up its position in 2003 as a seller to become number one buyer by 2030.

Table 5.9 shows that the largest buyers of livestock products will be the industrialized coastal regions South, East and North, with increasingly large net inflows of meat and milk,. Although by 2030 *meat* supply in these regions is 50% to 100% above the level of 2003, this is not sufficient to keep up with the demand increases resulting from rising per capita incomes and immigration-induced population growth. Also the traditional meat surplus region Southwest would become a deficit region due to rising demand. Northeast and Central will continue to be the leading net contributors but the rise of their surpluses is moderate. East will remain the largest *milk* buyer, with an inflow more than three times as high as in 2003. In North, a similar increase of milk inflow will be required in spite of the considerable supply increases. South is the third milk-buying region, although their per capita demand levels remain far below the levels in East and North. Remarkably, Northwest does not become a major milk-exporting region since its own demand rises just as fast as its production. For *eggs*, there is no significant change between 2003 and 2030, with North, Northeast and Southwest keeping up as selling regions.

Given the impressive surge in meat production and the lower growth rates in crop production, the large increases in feed inflows into the three industrialized coastal areas North, East and South appearing in Table 5.10 do not come as unexpected. Yet, some qualifications are in order. First, North, traditionally a maize-selling region, by 2030 has turned into a maize buyer, albeit a modest one. South and East were in 2003 net sellers of carbohydrate feed and remain so, but with lower outflows. The picture is similar across the three regions for protein feed only, with large increases in inflow throughout. While every region (with the exception of Plateau in 2003) will continue to be buyer of protein feed, the net inflow is going to double in South, East, and North. Only for Southwest the demand increase for protein feed will be rather modest, due to the relatively large share of draught animals and traditionally raised pigs and chicken in its livestock system. Compared with protein feed, the changes in net outflows will be less pronounced for carbohydrates, with the exception of North and Northwest.

One may observe in Table 5.10 that maize output in the two major maize-producing regions Northeast and North is increasing only at a limited pace, for North even surpassed by its own demand for maize, despite their often mentioned high potential referred to in section 2. As a result, North becomes a maize importer. Net maize exports from Northeast remain about constant (if one disregards the impact of the stock reducing operation of 2003), as high as about 18 million ton. Figure 5.1 provides more detail. The upper panel shows the distribution of maize production over the counties in 2003, distinguished by level of county output. Apart from some areas in Southwest and far Northwest, the major maize producing counties are indeed concentrated in Northeast and North. However, as shown in the lower panel, the increases between 2003 and 2030 are distributed more evenly over the four producing regions and do not show a strong advantage of North and Northwest. In fact, in both regions several counties have no increase at all (green-colored).

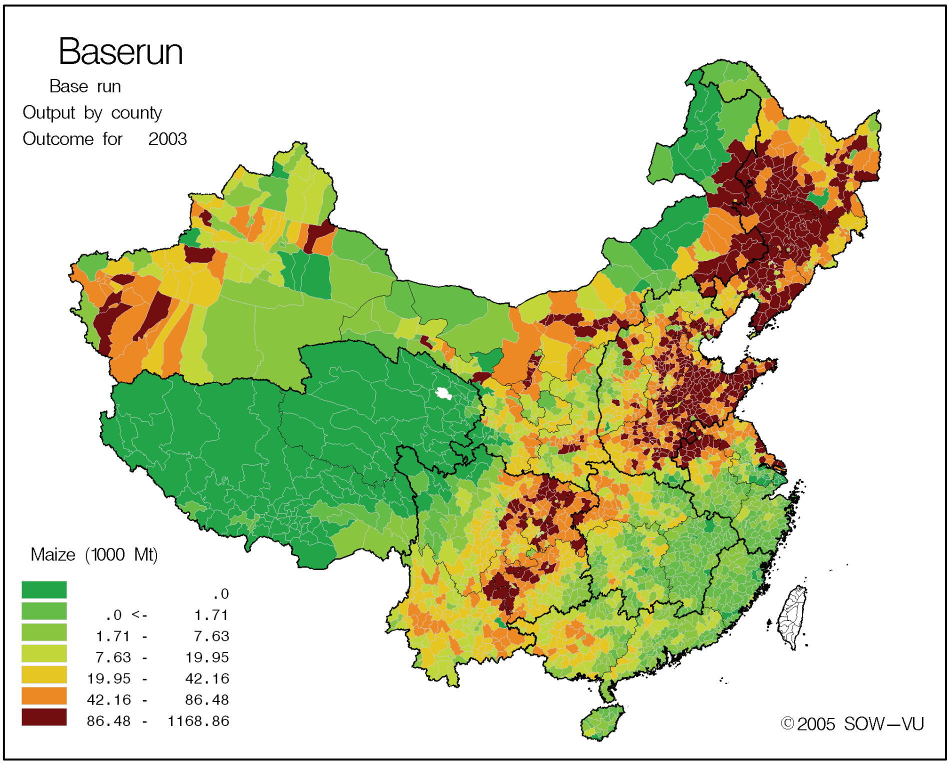
Table 5.10 Regional supply, demand, and net outflow of feed products under baseline

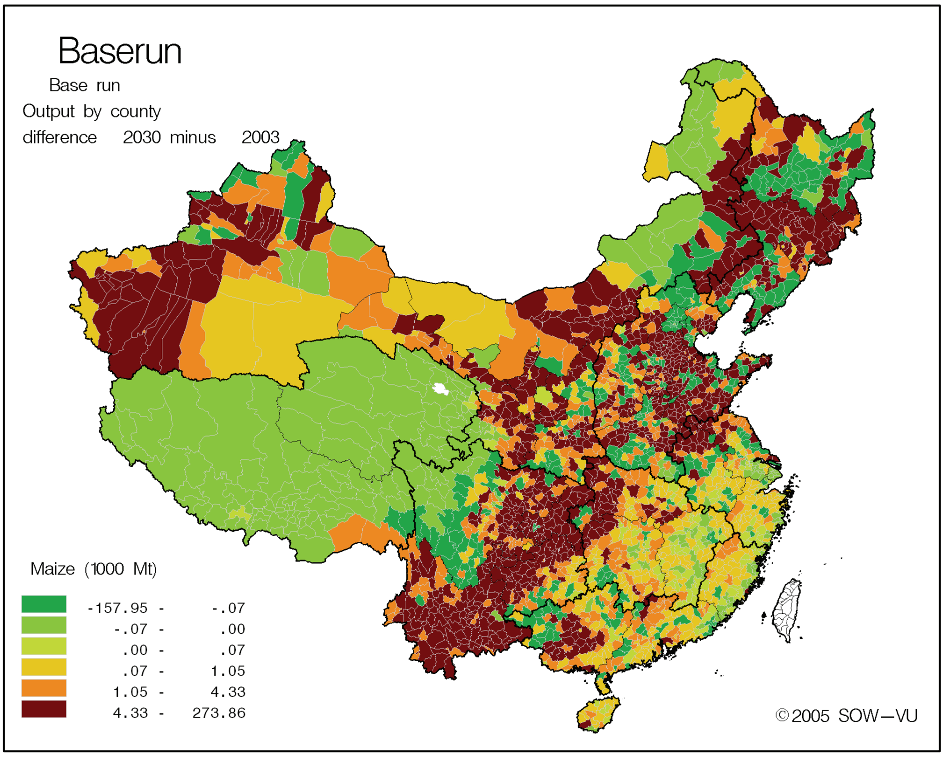
Products	Maize		Carbohydrate feed		Protein feed	
	2003	2030	2003	2030	2003	2030
Supply						
North	36.9	39.2	61.8	53.8	47.7	52.4
Northeast	30.7	32.5	23.3	21.6	19.0	21.0
East	5.1	5.5	45.6	41.0	36.6	39.0
Central	2.5	3.0	43.7	41.5	32.8	37.4
South	2.3	2.6	42.2	36.3	14.9	17.1
Southwest	14.7	18.1	56.5	52.3	20.4	24.1
Plateau	0.0	0.0	2.5	2.2	1.0	1.1
Northwest	15.0	17.8	29.9	27.0	18.5	21.4
Demand						
North	32.6	40.9	104.6	113.8	58.0	76.6
Northeast	12.8	14.7	27.3	25.7	29.0	35.0
East	8.4	9.5	27.3	24.0	46.3	59.1
Central	8.6	10.9	23.0	19.0	40.6	48.3
South	11.5	19.2	28.9	30.7	26.0	41.7
Southwest	32.8	35.9	88.9	82.0	30.9	32.9
Plateau	0.7	1.3	5.1	8.7	1.0	1.7
Northwest	6.1	8.5	22.1	28.5	19.4	31.7
Net outflow						
North	10.9	-1.6	-42.8	-60.0	-10.2	-24.2
Northeast	23.8	17.8	-4.0	-4.1	-10.0	-14.0
East	-2.4	-4.1	18.4	17.0	-9.7	-20.1
Central	-5.6	-7.9	20.7	22.5	-7.8	-11.0
South	-8.8	-16.6	13.3	5.6	-11.1	-24.6
Southwest	-15.5	-17.8	-32.4	-29.8	-10.5	-8.8
Plateau	-0.7	-1.2	-2.6	-6.6	0.1	-0.6
Northwest	11.8	9.3	7.7	-1.4	-0.9	-10.3

Notes: - maize volumes are expressed in million tons, carbohydrate feed and protein feeds in million Gcal,
- maize includes both food and feed,
- the 1997 and 2003 stock decreases of maize are omitted from the table, as in table 5.3.

We observe that in Northeast, where the baseline scenario assumes a conversion of 2 million ha of rainfed land into irrigated land and orchards, the moderate increase of maize output must primarily be written on account of the relatively poor profitability as compared to other crops. Table 5.8 shows that the output of all other crops, except oil crops, grows faster than maize. Given the presence of the city of Dalian as one of the largest ports for maize import and export, world prices have a strong influence on the maize market in this region. The resulting increase in farmgate prices by about 0.8% annually is apparently insufficient. Especially the newly irrigated land is seen to stimulate primarily rice output. In North, the same profitability issue plays a role but here both irrigated and rainfed land area is diminishing in the baseline scenario, hence ruling out the possibility of significant expansion in maize production. We return to this issue when discussing the outcomes of the enhanced irrigation scenario in the next section.

Figure 5.1 County level maize production in baseline in 2003 and 2003-2030 increase





5.4 Farm incomes and composition of value added

The combined effects of economic growth, urbanization, trade liberalization, environmental protection and technical progress will lead to significant changes in agricultural systems, with major consequences for farm employment and farm incomes, especially compared to the non-agricultural sector. The present subsection reports on these impacts. As mentioned earlier, the impacts are to some extent already captured exogenously through the scenario specification of available farm labor, machinery, crop land, grass land and stable capacities, because this specification has to anticipate all interactions at play, and is, therefore, not truly exogenous in a conceptual sense.

Nonetheless, given these resources, the farmers in each county decide endogenously on the intensity at which they will use crop land and stable types. They basically do this by shifting labor across the different land use options in response to their relative profitability, as determined by technical change and the prevailing market prices of inputs and outputs.

We may recall from section 3 that the model distinguishes three land use types in cropping (irrigated, rainfed and orchard), four land use types in raising ruminants (grazing, draught, traditionally mixed and specialized dairy) and two land use types in raising non-ruminants (traditionally mixed and intensified). As seen in Table 4.5, the baseline crop land scenario assumes declining irrigated and rainfed areas, with irrigated land in Northeast as the only exception, and increasing orchard areas. For ruminants, the scenario assumes declining stable capacities of draught animals but increasing capacities in grazing – made possible via grassland improvement and more than compensating for the effect of declining areas –, in traditionally mixed farming, and, very significantly, in specialized dairy farming (Table 4.7). We note that intensified cattle meat production, relatively unimportant in 2003, is not being distinguished as a separate land use type but included in the traditionally mixed system, whose gains in efficiency and stable capacity should partly be understood as intensification. For non-ruminants, the scenario assumes declining stable capacities of traditionally mixed farming and increasing capacities of intensified systems (Table 4.8).

As indicated earlier, output follows a somewhat different path, since the intensity of use of stable capacity is endogenous and trends of technical change may differ (Table 4.10). For crops, it appears that yields per hectare (expressed in terms of dry matter) increase between 2003 and 2030 in each region on irrigated as well as rainfed land, on average at about 0.6% annually, which is in each region higher than the rate of loss in crop land. Hence, crop output increases on both irrigated and rainfed land. For livestock, output developments for the different land use types are presented in Table 5.11.

Table 5.11 indicates that expansion of the traditional modes of production will continue in the next three decades, despite the declining stable capacities. Their profitability remains good, due to increased demand for meat and milk, resulting in steadily increasing farm gate prices. However, intensified systems will dominate eventually. For example, in 1997 the intensified pork production system accounts for 20% of pork output, against 52% in 2030. The shift is even more evident in poultry production, from 43% in 1997 to 78% in 2030. For milk the changes are also spectacular, with a nationwide increase of the output share of the specialized sector from 23% in 1997 to 62% in 2030.

Table 5.11 Livestock production under different farming systems (million tons)

	1997	2003	2010	2020	2030
Beef and mutton					
Grazing system	1.01	1.11	1.24	1.44	1.66
Trad.mixed system	2.99	3.24	4.12	5.40	6.36
Other (draught and intens. dairy)	0.61	0.62	0.61	0.57	0.51
Pork					
Trad. mixed system	22.98	25.05	25.59	26.79	25.39
Intens. system	5.67	9.67	15.36	22.17	27.94
Poultry meat					
Trad. mixed system	3.68	3.71	3.59	3.56	3.26
Intens. system	2.80	4.46	6.64	9.09	11.33
Milk					
Draught animal system	1.88	1.82	1.67	1.41	1.09
Grazing system	2.49	2.43	2.64	2.87	3.09
Trad. mixed system	3.32	3.57	4.56	5.87	6.73
Intens. dairy farming	2.35	5.84	9.93	14.37	17.80
Egg					
Trad. mixed system	7.29	7.51	7.16	7.11	6.49
Intens. system	5.43	8.70	13.10	18.28	22.69

In view of the rising scarcity of animal feeds, the turn to intensification is a necessary step, as the traditional systems, while effective in their use of crop and household residuals, have far more unfavorable feed-to-meat conversion rates.[24] Table 5.12 shows the development of feed demand in the different systems, for local and tradable feed separately. We observe that the role of local feed, although declining in relative terms, remains important. Measured in absolute amounts, its use even increases. Together with the Solow-neutral technical progress and the shift to intensified systems, this persistence of local feed supply keeps growth of the demand for tradable feed moderate compared to the output growth of the livestock sector, as was already apparent in Table 5.4.

At the same time, the trend towards intensification has important social implications, since the traditional livestock sector offers essential income earning opportunities to poorer farmers. The distribution of farm labor and farm value added reflects the rising importance of the intensified sectors. Table 5.13 indicates that between 1997 and 2030, total farm labor will decrease from 253 million to 189.1 million full time equivalents (as specified in the scenario). But with the expansion of livestock production, the farm labor employed in this sector will increase from 38.7 million to 45 million in 2030, of which 11.8 in the intensified pork and poultry production, whereas farm labor employed in the cropping sector will decline from 214.3 million to 144.1 million, due to labor-saving technical progress but also due to labor shifts to livestock sectors.

[24] For non-ruminants (pork and poultry) the average energy input-output ratio of the traditional sector is 8.4 in 1997, declining to 6.5 in 2030. For the intensified sector it is 5.5 in 1997 and declines to 4.3 in 2003.

Table 5.12 Feed use under different farming systems (thousand Gcal)

	1997	2003	2010	2020	2030
Draught animal system					
Tradable feed	165.5	159.2	146.0	123.1	95.6
Local feed	205.1	199.7	186.8	163.1	133.3
Grazing system					
Tradable feed	7.1	15.0	11.6	13.9	17.8
Local feed	132.6	131.4	144.9	158.1	172.0
Traditionally mixed ruminants					
Tradable feed	97.7	101.0	121.4	147.8	163.7
Local feed	99.1	107.1	140.9	184.7	214.4
Specialized dairy					
Tradable feed	2.3	7.4	12.8	17.7	20.3
Local feed	1.2	1.2	1.2	1.2	1.2
Traditionally mixed non-ruminants					
Tradable feed	396.7	415.0	388.6	366.3	301.7
Local feed	174.3	173.6	173.0	172.0	166.6
Intensified non-ruminants					
Tradable feed	128.2	210.8	315.3	418.6	487.2
Local feed	10.1	10.3	10.6	11.0	11.5
Total livestock					
Tradable feed	**797.5**	**908.4**	**995.7**	**1087.4**	**1086.3**
Local feed	**622.4**	**623.3**	**657.4**	**690.1**	**699.0**

Table 5.13 Allocation of on-farm labor to land use type under baseline (million full-time equivalent year)

	1997	2003	2010	2020	2030
Crop sector	214.3	202.2	190.9	171.6	144.1
Irrigated land	120.4	105.3	101.5	89.5	73.6
Rain-fed land	85.4	87.8	79.7	72.4	61.2
Tree cropping land	8.5	9.1	9.7	9.7	9.3
Livestock sector	38.7	43.2	44.3	47.1	45.0
Draught animal system	5.1	4.8	4.2	3.3	2.4
Grazing system	1.4	1.3	1.4	1.4	1.3
Trad. mixed ruminant farming	4.4	4.5	5.3	6.3	6.6
Intens. dairy farming	0.2	0.4	0.6	0.7	0.8
Trad. mixed nonruminant farming	25.2	27.6	25.8	25.4	22.1
Intens. nonruminant farming	2.4	4.6	7.0	10.0	11.8
Total on-farm employment	253.0	245.3	235.1	218.7	189.1

Somewhat surprisingly, more labor is used on rainfed land in the period 1997-2003, whereas irrigated land sheds more than 10% of its labor. This difference is related to the difficult situation of food grains in those years of which the large majority (98% of rice, 85% of wheat) grows on irrigated land. After 2003, labor use on irrigated and rainfed land declines at about the same rate. Considering regional differences, employment in crop production declines above national average in East and Northeast, and below in South, Northwest and Southwest, as shown in Table 5.14. Rises in employment in livestock production are mainly found in South and Northwest.

Table 5.14 Allocation of on-farm labor to cropping and livestock by region under baseline (million full-time equivalent year)

	North	Northeast	East	Central	South	Southwest	Plateau	Northwest
2003								
Crop sector	49.0	9.6	31.1	27.2	26.6	39.9	1.0	17.9
Livestock sector	10.6	2.8	4.2	5.8	4.7	10.4	0.5	4.1
Total on-farm employment	59.7	12.3	35.3	33.0	31.3	50.3	1.5	22.0
2030								
Crop sector	33.8	6.0	20.6	18.7	21.2	29.6	0.7	13.5
Livestock sector	11.4	2.6	4.1	5.4	6.5	9.0	0.7	5.3
Total on-farm employment	45.2	8.6	24.7	24.1	27.7	38.6	1.4	18.7

Next, we turn to value added. Table 5.15 shows the farm value added (normalized to the 1997 price level) of the different land use types and the percentage of farm value added in total GDP. Before discussing the figures, we should emphasize that we consider in this section only the *incomes from farming* and not the *incomes of farmers* or *incomes of farm households*, which could be much higher due to off-farm activities and remittances from migrants. We observe that total farming value added is steadily growing from 1,223 billion Yuan in 2003 to 2,871 billion Yuan in 2030, which means a fair increase of 3.2% annually. However, this rate is not enough to keep up with the non-agricultural sector that grows each year with 6.3%. Hence, the share of crop and livestock farming in total GDP falls dramatically from 9.8% in 2003 to 4.4% in 2030.[25]

Whereas the value added in the crop sector rises slowly at an average annual rate of 2.3%, reaching 1.8 times the 2003-level in 2030, the value added in the livestock sector will increase from 369 billion Yuan in 1997 to 1,340 billion in 2030, amounting to an annual growth rate of 4.9%. Therefore, its contribution to farm value added will rise from 30 to 47 percent, mainly earned in the production of pork and poultry. In conformity with the trends in output growth in Table 5.11, the share of the intensified sector in the earnings of pig and poultry farms rises significantly, from 28% in 2003 to 55%, hence by more than half, in 2030. We remark that the negative sign of farm value added in the draught animal system is due to the fact that the value of the draught animal power for crop production and local transportation is not accounted for in the table. This exclusion implies that the value added of livestock is underestimated and the value added of the crop sector is overestimated.

[25] Farm value added is relatively low in 2003 due to the reduced output and unfavorable farm price of rice and wheat. The Statistical Yearbook (NBSCa, 2004) mentions for 2003 a higher percentage (13.5%) but this figure includes also forestry and fisheries, together close to 3% of GDP.

Table 5.15 Farming value added and its share in total GDP under baseline (billion Yuan)

	1997	2003	2010	2020	2030
Cropping sector	819.2	834.4	1250.3	1481.1	1525.6
Irrigated cropping	498.0	406.9	699.7	819.2	827.4
Rainfed cropping	277.3	371.3	477.7	582.5	614.2
Tree cropping	43.9	56.2	73.0	79.4	84.1
Livestock sector	155.4	369.3	568.4	987.0	1339.8
Draught animal system	-34.0	-23.6	-24.2	-20.9	-14.0
Grazing ruminant farm	11.9	16.1	19.7	24.7	34.0
Trad. ruminant farm	2.4	24.4	32.4	54.0	91.9
Intens. dairy farm	3.7	9.5	14.0	17.9	20.9
Trad. nonruminant farm	136.8	245.3	323.1	481.3	549.0
Intens. nonruminant farm	34.5	97.5	203.5	430.0	658.0
Related sectors	20.3	18.7	14.0	8.9	5.3
Farming GDP	994.8	1222.5	1832.7	2476.9	2870.7
Total GDP	7658.6	12484.8	21326.1	39679.6	64768.9
Share of farming in GDP (%)	13.0	9.8	8.6	6.2	4.4

Note: related sectors cover collection of household waste, nightsoil and green feed

By combining Table 5.15 with Table 5.13, we can obtain the value added per farm worker, shown in Table 5.16. On average it grows at the rate of 4.3% annually, about 3.6% in cropping and 4.7% in livestock farming. Although less than in non-agriculture, these rates are appreciable, and mainly due to the labor out-migration from agriculture leaving more land per remaining worker, to the intensification of the livestock sector, and to the expansion of fruits and vegetables, as well as to the rising prices of livestock products.

Nonetheless, per capita growth of overall GDP of around 5.8% is much higher, which means that the income gap between the farm and non-farm sector will widen in the next three decades, and suggests that stronger labor outmigration will be required and that development of the non-farm sector should extend deeper into rural areas so as to provide sufficient off-farm employment to farm family members. Indeed, the “New Rural Development Program” initiated in early 2006 recognizes these tendencies and has, therefore, adopted targeted and far-reaching measures including abolition of agricultural tax, direct income support, input subsidies, and large increases in agricultural R&D and rural infrastructure investment to address the problems.[26]

[26] The New Rural Development Program was launched just before the Eleventh Five-Year Plan (NDRCb, 2006). In fact, its main content coincides with the latter’s second chapter ‘Building a new socialist countryside’. Its text can be found on http://news.sina.com.cn (in Chinese).

Table 5.16 Value added per farm worker, by land use type

	1997	2003	2010	2020	2030
Cropping sector	3820	4127	6552	8632	10584
Irrigated cropping	4135	3863	6893	9157	11237
Rainfed cropping	3244	4231	5997	8041	10040
Tree cropping	5148	6173	7545	8197	9013
Livestock sector	4028	8578	12841	20968	29800
Draught animal system	-6605	-4939	-5778	-6323	-5813
Grazing ruminant farm	8715	12415	14585	18319	25969
Trad. ruminant farm	544	5462	6104	8621	13924
Intens. dairy farm	24800	25730	24509	25183	26821
Trad. nonruminant farm	5438	8898	12512	18950	24829
Intens. nonruminant farm	14315	21344	28946	42830	56000
Average	3852	4908	7736	11288	15153

Finally, we remark that Table 5.16 clearly shows that the level of value added per unit of labor is higher in the livestock than in the cropping sector, and that the gap will increase over time. This reflects the differences in the amount of capital (buildings, machinery, animals, land) per worker, leading to a steeper decline of the marginal labor productivity curve in the livestock sectors and, therefore, to a larger discrepancy between average and marginal labor productivity. The gaps are large especially for the intensified sectors but also grazing and traditional pork and poultry appear to have considerably higher levels of value added per worker than cropping. For intensified dairy the development over time is not that promising in this scenario, due to the gradual decline of world milk prices and the reduction of import tariff rates that have a depressing effect on the domestic market prices, as seen already in Table 5.8.

Regarding the regional distribution of value added, the highest growth rates in cropping are found in Southwest (2.8%), Northwest (2.6%) and South (2.6%), and the lowest rates in Northeast (1.6%) and Plateau (1.8%), as can be inferred from Table 5.17. As a result, the North region will keep the largest value added in crop production, but Southwest and South will come close, leaving East and Central behind. Although these rates may seem rather similar, compounding over thirty years they lead to a value added in 2030 that is 2.1 times as high as in 2003 in Southwest but only 1.5 times as high as in 2003 in Northeast.

The low growth of Northeast is surprising, given the expansion of its irrigated area and its relatively high rate of technical progress assumed in the scenario. The question is, therefore, whether it is due to low output prices, high input prices or shortage of labor (and equipment). It appears that the trends in the market prices are relatively uniform across regions, as was seen already in Table 5.5, and this also holds for farmgate prices (not shown here separately).[27] Hence, labor availability would seem to be the basic constraint. Although crop labor input requirements per hectare are low in Northeast (due to the short growing season), the baseline scenario assumption of 1.3% annual decline in farm labor, as specified in Table 4.9 following the decline

[27] Although the farmgate price *level* of certain crops (rice, vegetables and especially wheat) is lower in Northeast than in other regions, this difference cannot explain the low growth rate.

in rural population, appears to be severe causing aggregate crop yields to improve only slowly between 2003 and 2020 and even fall afterwards, in contrast to all other regions.

Table 5.17 Gross value added of crop and livestock sector and total GDP

	1997	2003	2010	2020	2030
Crop sector (billion Yuan)					
North	167.2	175.1	264.5	296.6	299.5
Northeast	66.7	56.2	84.4	93.2	86.6
East	144.7	138.0	196.6	229.5	232.5
Central	131.7	123.1	177.0	204.1	212.6
South	123.1	142.9	221.5	277.7	282.4
Southwest	122.7	133.7	203.6	258.0	282.8
Plateau	2.6	2.5	3.4	3.9	4.0
Northwest	60.4	63.0	99.3	118.2	125.2
Livestock sector (billion Yuan)					
North	26.9	79.1	117.1	205.4	283.5
Northeast	16.2	36.2	52.2	89.0	119.6
East	23.6	49.3	73.5	121.4	160.2
Central	27.8	56.4	85.9	147.7	193.8
South	30.7	60.6	102.6	184.2	240.9
Southwest	10.6	50.1	82.5	148.3	206.0
Plateau	2.1	3.8	5.7	9.1	14.2
Northwest	17.5	33.8	48.9	82.0	121.6
Total GDP (billion Yuan)					
North	1895	3123	5376	10016	16240
Northeast	725	1091	1711	2884	4321
East	1713	2867	5024	9543	15736
Central	810	1306	2158	3818	5846
South	1287	2204	3996	8117	14382
Southwest	733	1130	1818	3098	4719
Plateau	27	43	71	129	215
Northwest	469	722	1172	2078	3317

With respect to value added in the livestock sector, the largest increases are in Southwest (5.4%), South (5.2%) and Plateau (5.0%) and the smallest increases in East (4.5%) and Northeast (4.5%). In 2003, North, South and Central are the top three largest earners. In 2030, North and South maintain their ranking but Central is replaced by Southwest.

North is one of the traditional maize production areas. Given this ample availability of home grown feed, the easy access to imports and the vicinity of a number of large cities, the North region is well-placed to lift its livestock production. The Southwest region has been known for its low cost pork production in past decades, but the poor transportation facilities, hilly roads and the greater distance from many of China's major cities did hamper its exports of meat to other regions in recent years. With the increased demand from inside the own region, the assumed gradual reduction in transportation costs and the ample availability of farm labor, in the absence of sufficient non-agricultural employment, the livestock sector in this region will receive a boost in coming decades. In the South region, the increase of livestock production is largely driven by internal demand that actually surpasses its capacity, as was seen earlier in Table 5.5. Finally, we remark that in Northeast the livestock sector, although also suffering from scarcity in farm labor, becomes the dominant contributor to agricultural value added.

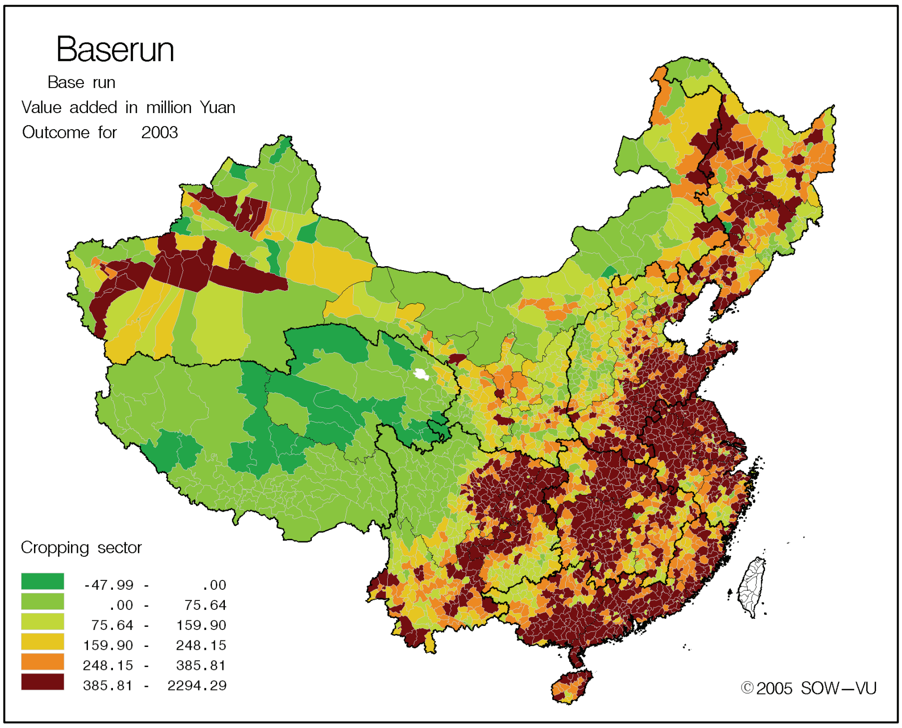
The maps of Figure 5.2 show how crop value added is distributed across the counties. We observe that the legend classes define absolute values irrespective of the size of the county, as opposed to per hectare values. As the regional boundaries also appear on the maps, distribution of value added across counties within a region can readily be read off. The upper panel shows the situation in 2003. The maps confirm that counties with the highest value added in crops are concentrated in the coastal areas North, East, South and in Central and Southwest, but not all over these regions. The lower panel shows the absolute increases between 2003 and 2030. The picture that emerges is rather differentiated, showing counties with large increases throughout most regions, intermingled with areas with lower increases. This shows that there is not a single compact ‘booming area’ that outperforms the rest of the country. For instance, in the Southwest region besides the area around the city of Chongqing, the province of Yunnan also performs very well. Figure 5.3 shows the corresponding maps for the livestock sector. In the upper panel we see that the areas with highest value added are concentrated in the hinterlands of the big cities, especially in South, East, Central and Southwest, whereas the lower panel indicates that the major increases from 2003 to 2030 generally take place in subsets of these areas.

Table 5.18 Share of cropping and livestock in total GDP (in %)

	1997	2003	2010	2020	2030
North	10.2	8.1	7.1	5.0	3.6
Northeast	11.4	8.5	8.0	6.3	4.8
East	9.8	6.5	5.4	3.7	2.5
Central	19.7	13.7	12.2	9.2	7.0
South	11.9	9.2	8.1	5.7	3.6
Southwest	18.2	16.3	15.7	13.1	10.4
Plateau	17.4	14.6	12.8	10.0	8.4
Northwest	16.6	13.4	12.6	9.6	7.4
China	**12.7**	**9.6**	**8.5**	**6.2**	**4.4**

Table 5.18 shows the relative importance of farming in each region measured as its share in total GDP. The shares are calculated from Table 5.17. Southwest will retain the highest share in 2030, but not reaching more than 10.4%, of which 6.0% crops and 4.4% livestock. Next, Plateau, Northwest and Central follow with shares from 8.5% to 7.0%, while for Northeast, North, South and East the shares are in the range from 4.8 % to 2.5% only. Clearly, as such these low shares of farming value added do not have to be interpreted as signs of trouble but they reinforce the point that outmigration has to be significant. To highlight the income position of the farming activities, we consider in Table 5.19 the value added per farm worker in the different regions, as derived from Tables 5.17 and 5.14.

Figure 5.2 County level value added from cropping in baseline in 2003 and 2003-2030 increase



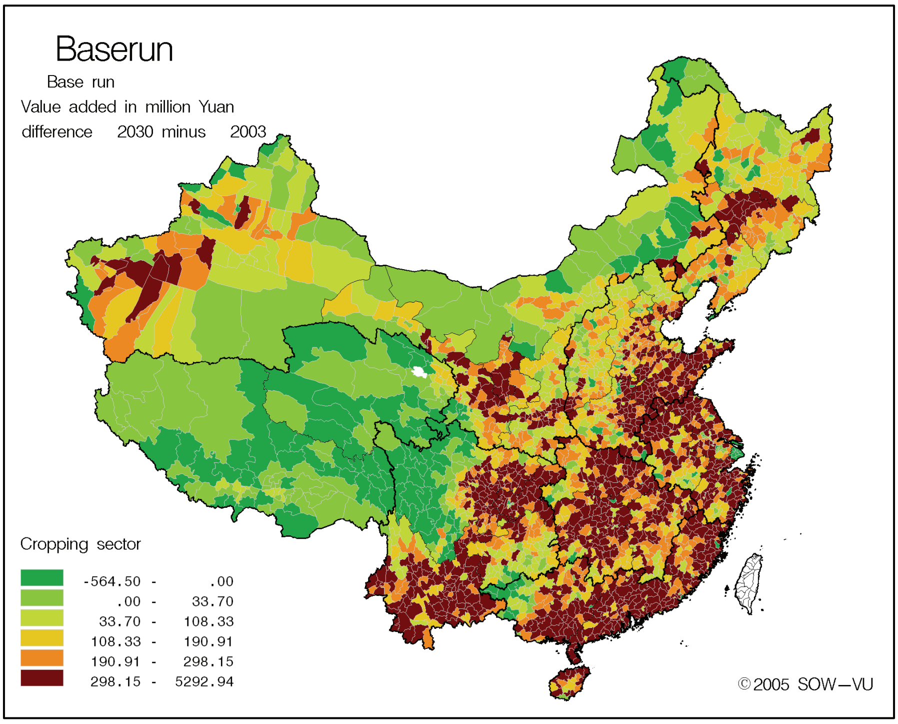
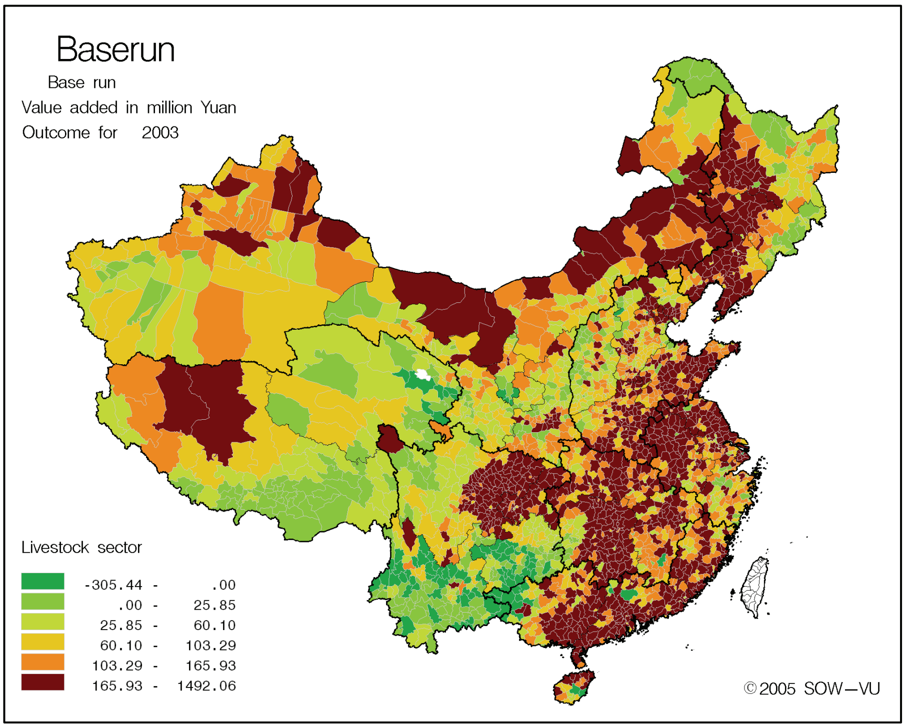


Figure 5.3 County level value added from livestock in baseline in 2003 and 2003-2030 increase



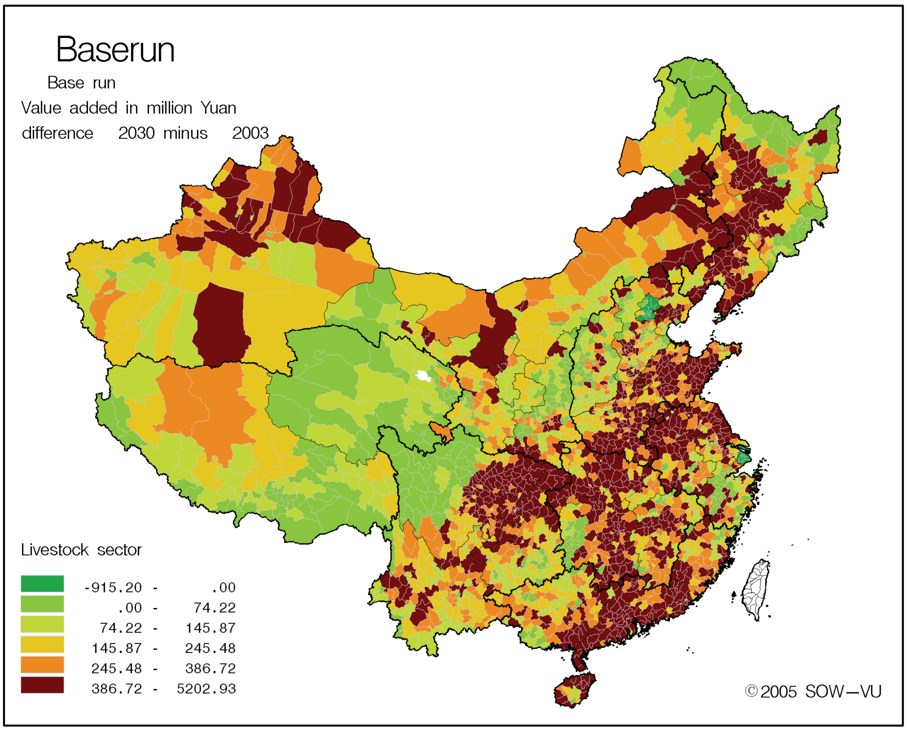


Table 5.19 Regional value added in Yuan per farm worker, baseline

	1997	2003	2010	2020	2030
Cropping sector					
North	3186	3571	5777	7328	8862
Northeast	6368	5880	9561	12257	14389
East	4380	4436	6860	9131	11275
Central	4534	4532	6980	9105	11368
South	4471	5375	8507	11243	13303
Southwest	2927	3351	5344	7438	9558
Plateau	2519	2490	3707	4583	5479
Northwest	3199	3527	5791	7507	9289
Livestock sector					
North	2912	7450	10633	17228	24784
Northeast	6675	12964	18985	31235	45824
East	6301	11846	17249	27393	39066
Central	5446	9739	14816	24824	36030
South	7161	12957	20074	30546	36943
Southwest	1075	4803	8065	14781	23021
Plateau	4929	8378	10000	13368	19944
Northwest	5009	8182	10769	15802	23162

Table 5.19 would more than Table 5.18 be a source of concern. For crops, the national growth rate of 3.6% for the value added per worker, seen in Table 5.16 above, appears to be rather uniform across regions. The outlier on the high side is Southwest with 4.0% and on the low side Plateau with 3.0%. For livestock, the growth rate of the value added per worker, nationally 4.7%, varies more. It is highest in Southwest with 6.0% and lowest in South with 4.0%. Nonetheless, in all regions it is below the growth rate of per capita GDP, with the exception of Southwest. But also here, growth rates are attributable to the intensified sectors as opposed to the traditional ones. Hence, the danger of increasing income gaps between farmers and non-farmers, expressed earlier at national level would seem to apply throughout China, across all regions.

Finally, we mention that the South region contrary to the concerns raised in section 2 in relation to its limited possibilities for expansion of feed output, has the highest rate of crop yield increase of all regions (in terms of dry matter, about 1.1% against 0.6% as national average), whereas in terms of value added the annual increase of 2.6% ranks third. Also for livestock, output increases of the livestock sector are among the highest, as seen in Table 5.9, and although these require more than a doubling of feed imports, the livestock value added rises at a rate of 5.2%, ranking second. Hence, agricultural developments in the South do not seem particularly alarming as compared to other regions, albeit that the degree of self-sufficiency becomes lower. The main concern is, as in all regions, the widening income gap with the non-farm sector.

5.5 Environmental pressure

Expansion of agricultural production creates strong pressures on the environment, of two kinds, one due to the intensified use of chemical inputs such as herbicides and fertilizers, the other to the discharge of organic manure and residuals from food processing.

China is the largest consumer of chemical fertilizer and worldwide accounts for 90 per cent of the increase in fertilizer use since 1981 (Liu and Diamond, 2005). Though there is significant scope for improving input use efficiency, the level of crop production anticipated for China in the next thirty years may require even further increases in fertilizer application. The next two tables report on the demand for chemical fertilizers projected by the model simulations, as well as on the use of organic manure. Table 5.20 presents the amounts per hectare and Table 5.21 the absolute volumes, both by region. The figures are weighted averages of the underlying separate figures for irrigated and rainfed crop land.[28]

Table 5.20 Organic and chemical fertilizer used per hectare, by region, under baseline (kg/ha)

	1997	2003	2010	2020	2030
Organic fertilizer					
North	72	76	84	89	90
Northeast	32	32	32	33	32
East	59	61	63	65	63
Central	91	94	99	98	90
South	100	109	123	143	155
Southwest	100	101	106	106	100
Plateau	27	29	42	49	52
Northwest	25	28	34	40	44
China	**63**	**66**	**71**	**75**	**74**
Chemical fertilizer					
North	424	457	479	492	495
Northeast	199	199	203	211	215
East	509	526	543	561	568
Central	444	460	494	525	551
South	456	472	520	576	601
Southwest	273	279	294	313	330
Plateau	90	89	84	83	84
Northwest	142	145	151	154	154
China	**325**	**338**	**354**	**369**	**376**

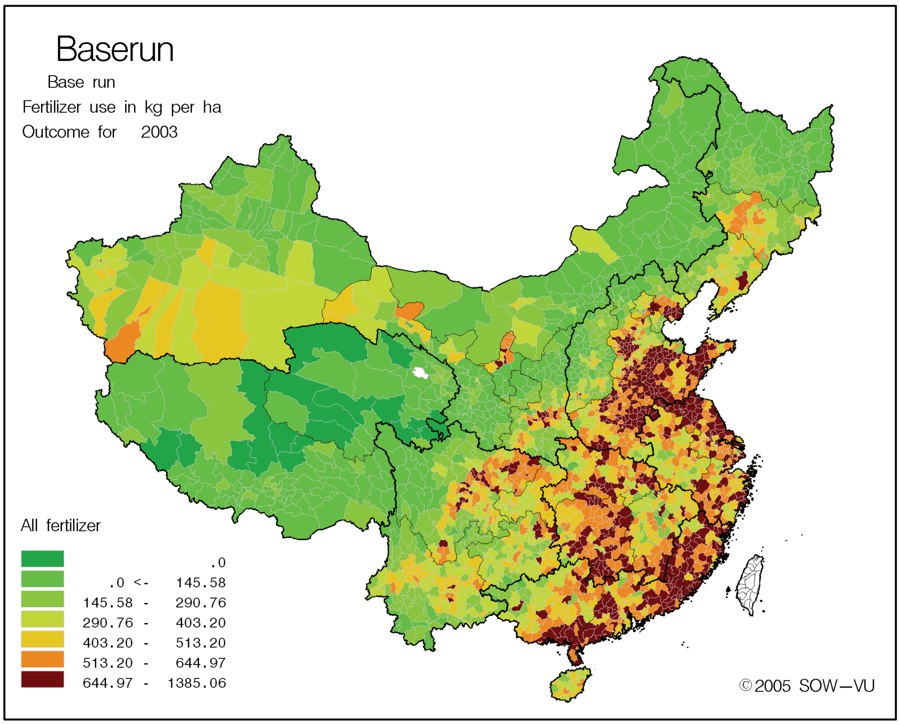
[28] In Tables 5.20 and 5.21 as well as in Figure 5.4, fertilizer use is measured in terms of its nutrient content, as the sum of N, K_2O and P_2O_5. Furthermore, they actually report on purchased (tradable) fertilizer, as opposed to local fertilizer. Since 10% of organic manure is considered tradable, the real share of organic manure is somewhat higher and the share of chemical fertilizer correspondingly lower than indicated.

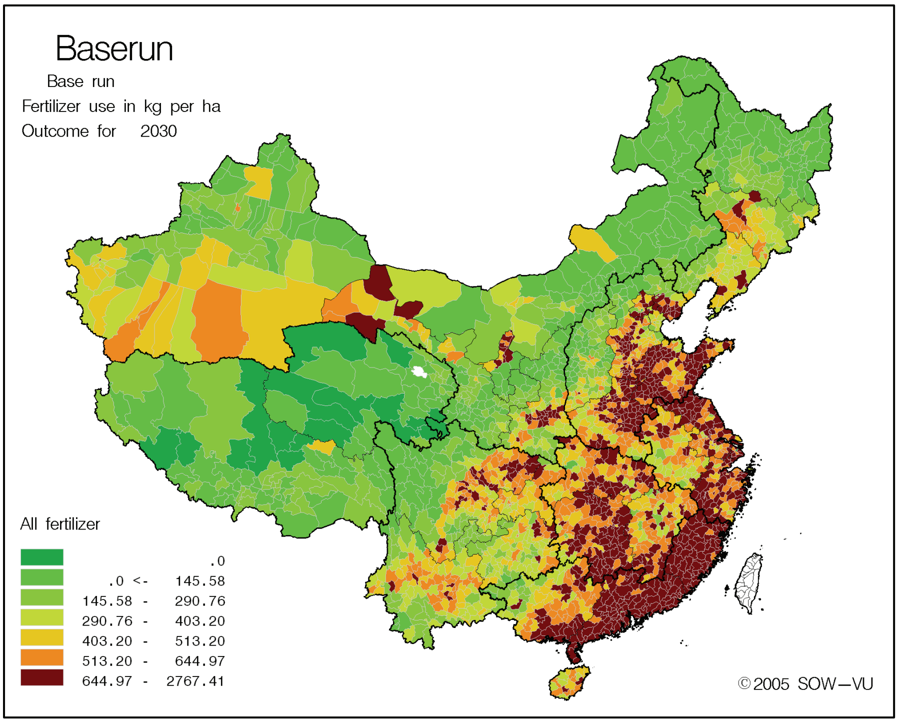
Table 5.20 shows moderate increases in the application per hectare. For the whole of China, on average, fertilizer use per hectare of cultivated land will increase from 404 kg in 2003 (of which 66 kg organic fertilizer and 338 kg chemical fertilizer) to 450 kg in 2030 (74 kg organic fertilizer and 376 kg chemical fertilizer). Organic fertilizer applied on irrigated land increases from 97 kg per hectare in 2003 to 108 kg in 2030 and on rainfed land from 38 to 43 kg per hectare. During the same period, chemical fertilizer applied on irrigated land increases from 508 kg per hectare in 2003 to 559 kg in 2030, whereas on rainfed land it increases from 189 to 207 kg per hectare. In terms of absolute amounts, the increases are even less since total arable land drops from 125.6 million hectare in 2003 to 116.6 million hectare in 2030. In 2003, total chemical fertilizer use in China is 42.5 million tons, and it will rise to 43.8 million ton only, as seen in Table 21.

Table 5.21 Total organic and chemical fertilizer used by region, under baseline (1000 tons)

	1997	2003	2010	2020	2030
Organic fertilizer					
North	2127	2156	2275	2370	2335
Northeast	652	659	682	691	657
East	807	810	825	812	758
Central	1088	1089	1103	1073	977
South	1007	1052	1137	1214	1208
Southwest	1842	1837	1874	1854	1723
Plateau	28	30	43	51	53
Northwest	586	630	734	867	936
China	**8139**	**8263**	**8673**	**8931**	**8646**
Chemical fertilizer					
North	12439	12986	13049	13048	12834
Northeast	4106	4147	4293	4414	4444
East	6984	7042	7064	7042	6867
Central	5293	5322	5528	5774	5971
South	4580	4565	4804	4901	4673
Southwest	5040	5061	5208	5447	5674
Plateau	93	93	87	86	86
Northwest	3346	3296	3303	3307	3258
China	**41882**	**42511**	**43336**	**44018**	**43807**

Figure 5.4 Per hectare fertilizer used at county level in baseline in 2003 and 2030





On the basis of Table 5.20, we can summarize the regional differences with respect to chemical fertilizer application as follows. North has high levels (634 and 205 kg/ha in 2003, on irrigated respectively rainfed land), but the growth rates are below average. In Northeast levels are rather low (333 resp. 166 kg/ha in 2003), and constant over the simulation period. East has high levels (601 resp. 333 kg/ha in 2003), with growth rate slightly below average. Central has average levels on irrigated land (525 kg/ha in 2003) and rather high levels on rain fed land (321 kg/ha) and growth rates are above average (0.7 resp. 0.6%). The South has both high levels (580 resp. 346 kg/ha in 2003) and high growth rates (0.9 resp. 1.0%), supplementing the already high use of organic fertilizer. Southwest applies at moderate levels (421 resp. 205 kg/ha in 2003), but growth rates are above average (0.8 resp. 0.5%). Plateau naturally has very low levels (102 resp. 82 kg/ha in 2003), that even decline over time because the availability of animal manure increases considerably. Finally, in Northwest levels are low (262 resp. 74 kg/ha in 2003), whereas also growth rates are below average.

It is important to note that chemical fertilizer use is far higher in densely populated regions than in remote areas. This only exacerbates the prevailing environmental problems. For example, in 1997 the use of chemical fertilizer already reaches on average 456 and 509 kg per hectare in the most developed regions South and East, respectively, and it would rise to 601 and 568 kg per hectare in 2030. If one includes organic manure, the amounts will be even as high as 756 and 631 kg per hectare, as was shown in Table 5.20. The distribution of this pressure over the counties is depicted in Figure 5.4. The upper panel applies to 2003, the lower panel to 2030. Both panels have the same legend classes, for ease of comparison. We observe that in 2003 the highest applications are found in pockets of the coastal regions North, East and South, and that by 2030 these hotspots have expanded considerably, especially in the South.

High application levels per hectare may lead to serious environmental problems since not all fertilizer applied by farmers can effectively be taken up by crops. In a study related to the Chinagro project, Ermolieva et al. (2005) present detailed nutrient supply and uptake calculations showing 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 provincial 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 the East). The authors estimate that crop production in 2000 has taken up about 15 million tons of nitrogen in total. This compares to applied amounts of about 24.5 million tons of nitrogen in chemical fertilizer and an estimated 8.5 million tons of N in livestock manure. Hence, given China's overall surface, the nitrogen released to the environment amounts to about 20 kg N per hectare of total land. For Jiangsu and Zhejiang, both in the East, and Henan and Hubei, adjacent provinces in North respectively Central, this value reaches well over 100 kg N per hectare, pointing to a substantial environmental pressure on soils and watercourses.

Regarding livestock production, the geographic concentration and increasingly intensive utilization of stable spaces may also cause serious nutrient overloads in surface water, groundwater and soils, and generate major emissions of manure-related gases into the atmosphere (methane, nitric and nitrous oxide, etc.). The manure composition in terms of nutrients, heavy metals and organic matter depends on a variety of factors, such as livestock category, production system and feeding characteristics. As an illustration, ex-post calculations based on the 2003 outcomes of feed intake by livestock system, estimate the aggregate amount of nutrients produced by stall-fed and otherwise confined livestock in China to be in the order of 15.5 million tons.[29] This amounts to approximately 114 kg of nutrients per hectare of cultivated and orchard land, which can be subdivided into 59 kg nitrogen (N), 26 kg phosphate (measured as oxide P_2O_5) and 29 kg potassium (measured as oxide K_2O). Pigs and poultry contribute about 50 percent of these nutrients. When comparing these figures with the cropping use of organic manure of Table 5.20,[30] we may conclude that in 2003 on average about 47% of confined animal manure nutrients is actually applied in cropping. The remaining 53% is a potential source of pollution, unless used for other purposes. In this environmental assessment it is assumed that manure from pastoral livestock is recycled on the grazing land or to a limited extent used as domestic energy source for heating and cooking.

Applying the same ex-post calculations to the 2030 baseline outcomes leads to a nutrient production in confined livestock systems of around 17.5 million tons in 2030, which amounts to 136 kg per hectare of available cultivated and orchard land, consisting of 70 kg nitrogen, 31 kg phosphates and 35 kg potassium. This amounts to an increase in manure nutrient supply per hectare of around 20% at national level between 2003 and 2030. As such, this average growth percentage would seem moderate, and must be seen in conjunction with the assumed steady rates of Solow-neutral technical progress in the livestock sectors. However, as was extensively discussed earlier the differences are large between as well as within regions.[31]

To sum up, both unused animal manure surpluses and losses in the application of fertilizer (of chemical and organic origin) lead to serious environmental concerns, now and even more in the future. Especially since the geographical variation in the ratios of stable capacities to crop land is wide, nutrient pressure may be strong locally, creating health risks to the population almost inevitably. Use of pesticides is likely to add to these problems but we cannot substantiate this claim on the basis of the Chinagro simulations, since pesticides are not identified as separate inputs in the model.

[29] The coefficients used in these calculations are reported in Appendix A. For the base year, they are consistent with the nutrient supply coefficients used in Ermolieva et al. (2005), i.e. 78.0, 11.8 and 1.0 kg per animal per year for respectively large animals, pigs and poultry.

[30] To make an exact comparison, we should undo the shift of organic to tradable fertilizer (+10%), deduct nightsoil (-20%) and make a correction for orchard land (-7%) in Table 5.20.

[31] Ermolieva et al. (2005) report a nutrient growth rate of more than 50% between 2003 and 2030 at national level. The difference with our outcomes is largely due to faster increases of the herd sizes of pigs, poultry and sheep in their baseline scenario.

6. Results for other scenarios

Here, we discuss the outcomes of the specified variants of the baseline scenario, and compare these to the baseline. We recall that the Chinagro model was designed as a tool for consultation on upcoming policy issues rather than as one that is tightly tailored to a fixed set of issues. The model produces outcomes through numerous and detailed tables and maps. A policy analyst in search of the answer to a particular question will have to consult these so as to follow the chain of causation from scenario to result. In general the question posed will be rather general, and at the beginning of the round of simulation exercises more oriented to a subject area than to a specific policy. The scenarios described in section 4 ask such questions: "How will opening up of trade in agriculture affect trade, regional distribution of production and incomes?", "How would faster growth impact on this?", and "To what extent can faster technological progress and reform of the sector help in addressing the problems?", and, finally, "What about the consequences of faster expansion of irrigation?".

Every such question can be expressed in a number of scenario runs, each of which produces a number of tables and maps far too large to be reported on in full in any paper. In fact, at a future, more practical stage of model application, the questions will hopefully become more focused, and the policy packages more specific but at present we report on scenario outcomes as a separate exercise that may highlight the model's response and future use.

The discussion of results will start with the impacts on prices and national commodity balances, followed by the regional effects on production, incomes, employment, and, finally, on the environment. We summarize in separate sections the main findings of each scenario: trade liberalization in 6.1, high income growth in 6.2, high R & D in 6.3 and enhanced irrigation in 6.4. Maps with county-specific effects are included in these sections but the tables with numerical outcomes are, for ease of comparison, presented jointly for all variants, in Appendix B.

6.1 Trade Liberalization Scenario

The *trade liberalization* scenario assumes a stronger reduction of agricultural border protection than the baseline assumption from 2003 to 2010, halving the 2003 tariff levels, and eliminates all taxes on international agricultural trade after 2010. Nonetheless, it can only be interpreted as depicting partial liberalization, because it maintains at their baseline level: world prices, prices of specific non-agricultural inputs such as fertilizer and margins for trade and transportation, as well as production factor availability in agriculture (total farm labor, machinery, farm land and stable capacities). Allowing for adjustment of world prices would presumably dampen the effects reported, accounting for cheaper non-agricultural input costs would make them more favorable for farm incomes, and including overall adjustments in factor availability to price changes would make these effects more pronounced.

Since, traditionally, China's trade regime in agriculture amounted to penalizing imports as well as exports of most commodities, liberalization promotes both imports and exports as it leads to a reduction of prices of imported goods (vegetable oil, sugar and, especially, milk and after 2010 also white meat), whose production drops and consumption increases, and a rise in the price in exported goods (rice, fruits and vegetables), whose production increases while consumption falls. Most pronounced is the effect on sugar, where abolition of protection leads to a significant drop in supply, which in combination with an increase in demand causes imports to rise appreciably. For the commodities in autarky in the baseline, the effect of liberalization is not easily predicted but it appears that wheat and eggs remain in autarky and ruminant meat is imported but only in small amounts. The supply-demand balances are shown in Tables B.1 – B.3 and the prices in Tables B.5 and B.6,[32] whereas Table B.4 expresses consumption of grain and meat in per capita terms.

Maize had an effective subsidy of some 15% on exports in 2003 (to reduce the high stock levels), keeping prices slightly above world level, which turned after 2003 into a supply deficit with a limited tariff in the baseline. Eliminating this tariff incites increased use and also somewhat discourages production of maize, leading to increased imports.

Protein feeds and carbohydrates are produced domestically and traded internationally but tariff rates are neglected in the model for these composite commodities. They are used in compound feeds that compete with maize and various locally produced feeds or grown as fodder or derived as crop residuals, in which case their feed value only constitutes part of the product value of the crops they originate from. At the same time, demand for these feeds primarily depends on the value of the livestock they nourish. Consequently, the effects of liberalization on these markets are rather intricate. The simulation shows that, nationwide, production volumes of carbohydrate feed and protein feed are not affected very much but their intermediate use declines slightly causing net import volumes to go down somewhat, with about one percent compared to the 2030 baseline outcome.

Overall, the net agricultural trade deficit appears to increase but not dramatically, from 28.9 billion USD in the baseline to 35.2 billion USD. On balance consumers gain from lower prices: per capita grain consumption rises from 155.0 to 155.2 kg per year, meat and egg consumption from 77.0 to 79.5 kg per year, and energy intake from 2828 to 2866 kcal per day, all in 2030 (Table B.4). National self-sufficiency in grains is hardly affected, with the rate for rice going up from 103% to 105%, for wheat constant at 100% and for maize falling from 84% to 82%.

The supply effects summarized above for the country as a whole are generally found in all regions, with the relative changes in each county depending on the magnitude of the price impacts and the substitution possibilities. Figures 6.1 – 6.4 show the geographical distribution of the effects for four commodities (maize, sugar, fruit and pork), measured in thousand metric ton of output difference in 2030 compared to the baseline. Evidently, these absolute magnitudes of change to a large extent depend on the importance of the county for the production of the commodity concerned.

[32] The market price trends are rather similar across all regions. Therefore, to reduce the amount of information, Tables B.5 and B.6 show the prices for only three regions (North, Central and Southwest).

Figure 6.1 County level maize production: difference between Liberal and Baseline, 2030

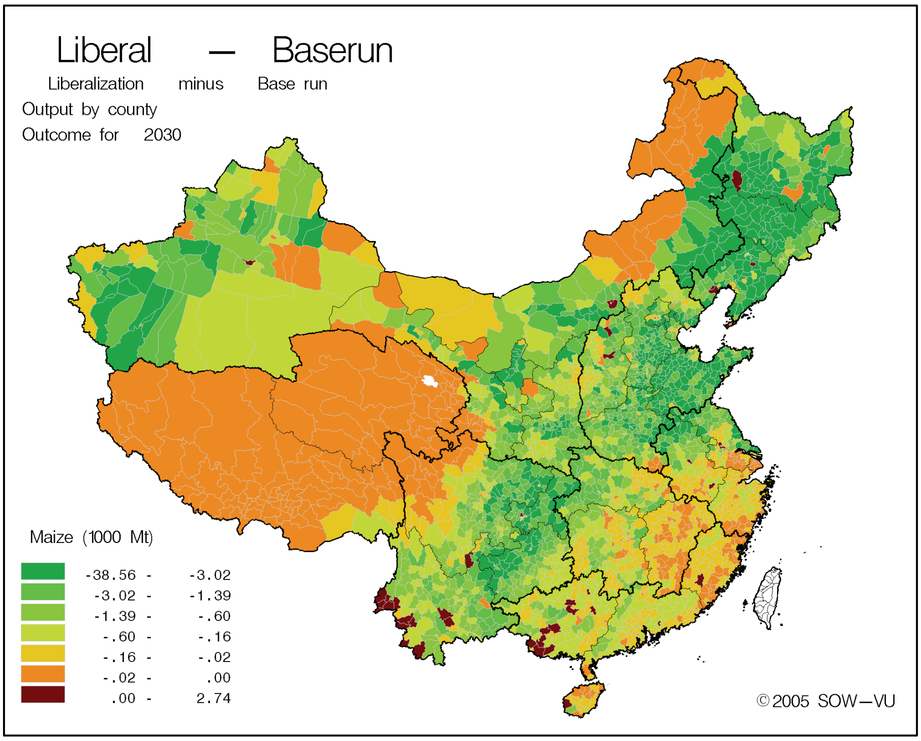


Figure 6.2 County level sugar production: difference between Liberal and Baseline, 2030

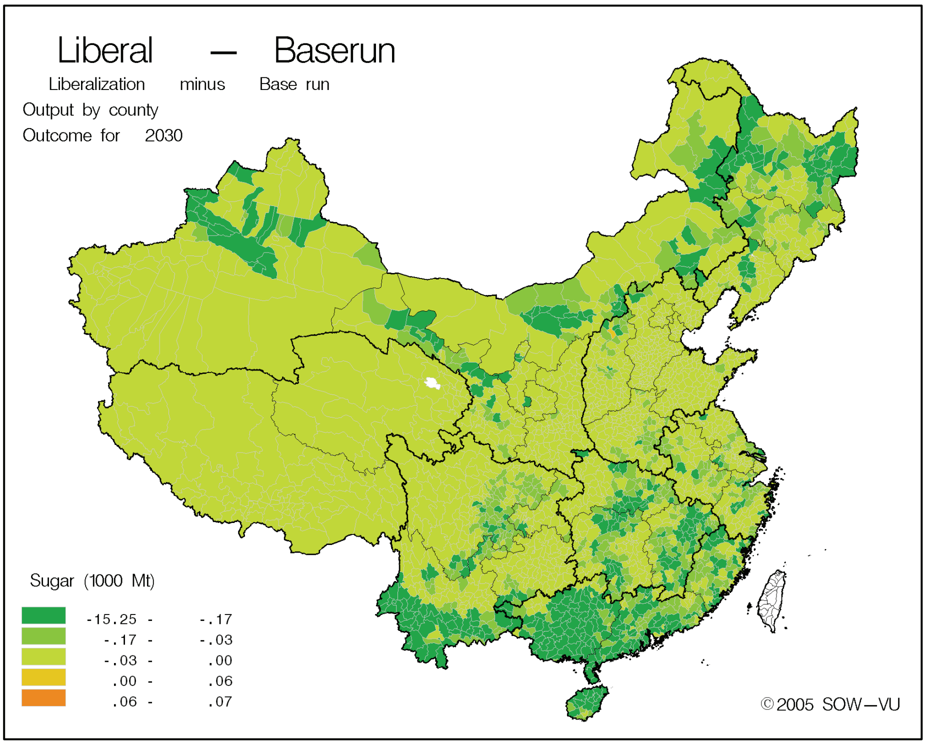


Figure 6.3 County level fruit production: difference between Liberal and Baseline, 2030

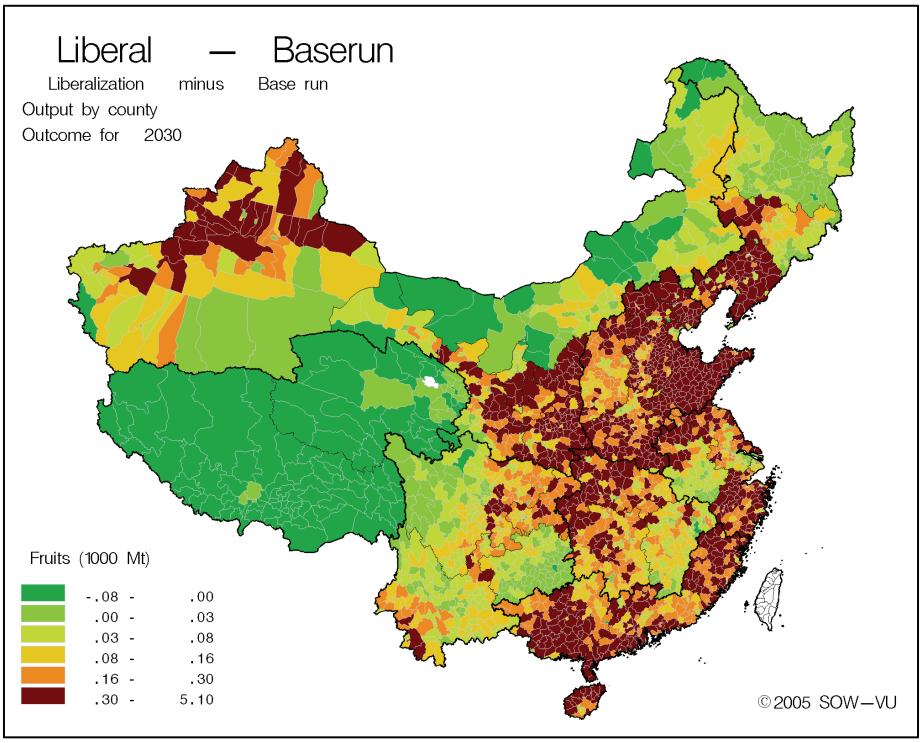
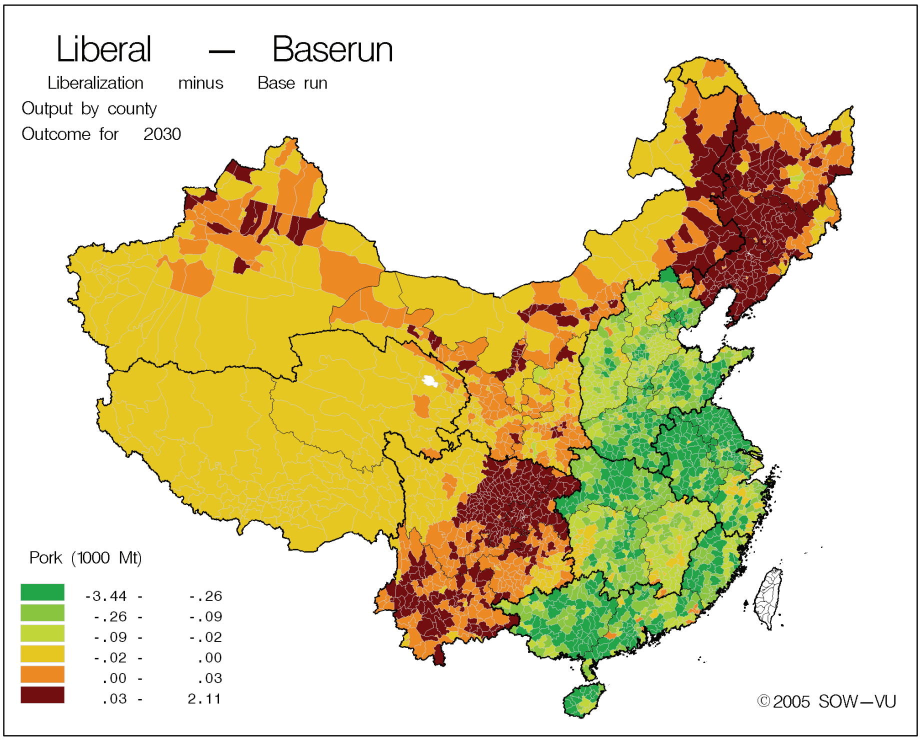


Figure 6.4 County level pork production: difference between Liberal and Baseline, 2030



Declines in maize output are found all over Northeast, North, Southwest and Northwest, the major producing regions. Yet, more scattered increases can be observed also, especially in South and Southwest where maize apparently replaces sugar, whose price drops even more. Sugar output decreases in all producing regions, as shown in Figure 6.2, both for sugarcane in South and Southwest and for sugar beets in Northeast and Northwest. Fruit output increases almost everywhere, with emphasis on North, East and South. These increases refer only to annual crop land and are, therefore, limited in size, since the scenario keeps orchard land the same as in the baseline. The effects on pork output are rather subtle, since farmers in remote counties are protected to a certain extent by trade margins that are relatively high for animal products, making them less vulnerable for price falls. Figure 6.4 shows a clear distinction between the coastal regions North, East and South with lower output and the more remote regions Northeast, Northwest and Southwest with higher output. In this respect, we may also note that the overall difference with the baseline is relatively small, nationwide a decline of only 260 thousand ton.

The allocation of inputs between sectors naturally reflects the changes in commodity prices and outputs under trade liberalization. For example, since the rice, fruit, and vegetable prices are higher due to elimination of export tariffs while the livestock price drops, labor is attracted to the crop sector (Table B.7). Farm employment accordingly has shifted by 0.7 million man-years from livestock to cropping in 2030. The effect on farmer's incomes turns out to be negative: whereas cropping value added remains about constant in 2030, value added in livestock activities declines from 1,340 billion Yuan to 1,224 billion Yuan, hence by 10 percent almost (Table B.8). Whereas this decline in livestock incomes hits every region, it is highest in the densely populated coastal regions East and South, with about 16 percent (Table B.9). For South, the negative impact of falling sugar prices on cropping value added appears to be compensated by the other crops, especially rice and vegetables. The same trends show up in Table B.10 that reports on the value added per laborer: for cropping the growth rate in the period 2003-2030 is about the same as in the baseline, but for livestock it is clearly lower (4.4% instead of 4.7%), especially in South (3.4% instead of 4.0%) and East (4.0% instead of 4.5%).

Figures 6.5 – 6.7 show the effects on value added at county level, expressed in million Yuan difference in 2030, compared to the baseline, for cropping, livestock and total farming, respectively. Although total cropping value added is about the same as in the baseline, Figure 6.5 reveals a mixed pattern of increases and decreases, with the winning counties mainly in the rice-producing regions East, Central and South and the losing ones in the maize-producing regions North and Northeast. Livestock value added appears to decrease everywhere, despite the cheaper maize feed, with the largest absolute declines in the counties of the coastal regions East and South, as was seen earlier. In only a very few counties the positive effects on crop value added can dominate the negative effects on the livestock value added. Hence, under liberalization most counties lose in total value added (Figure 6.7).

Figure 6.5 County level crop value added: difference between Liberal and Baseline, 2030

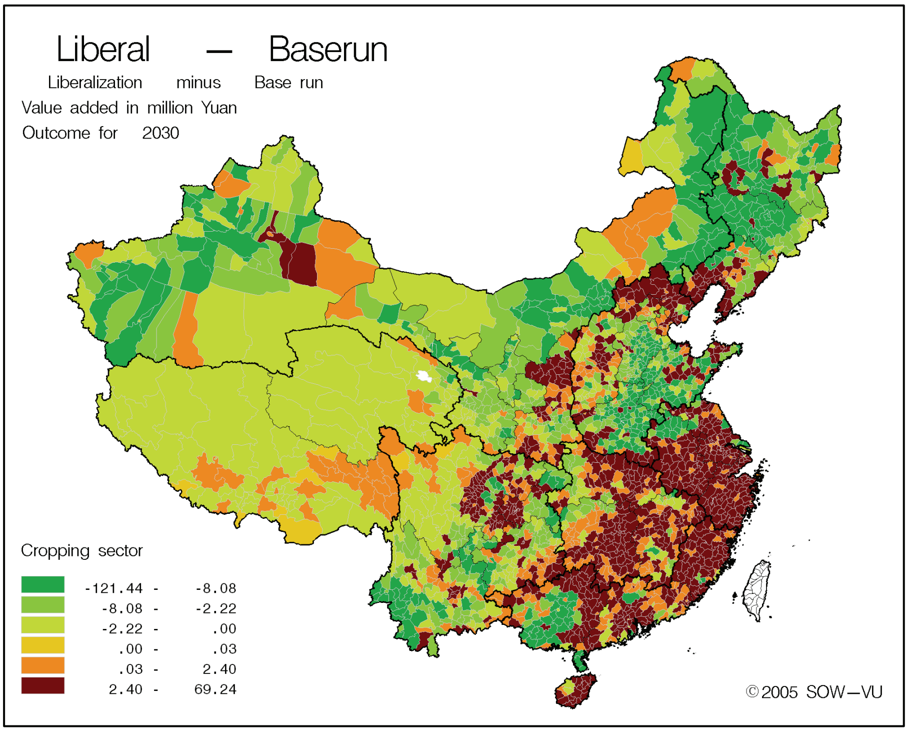


Figure 6.6 County level livestock value added: difference between Liberal and Baseline, 2030

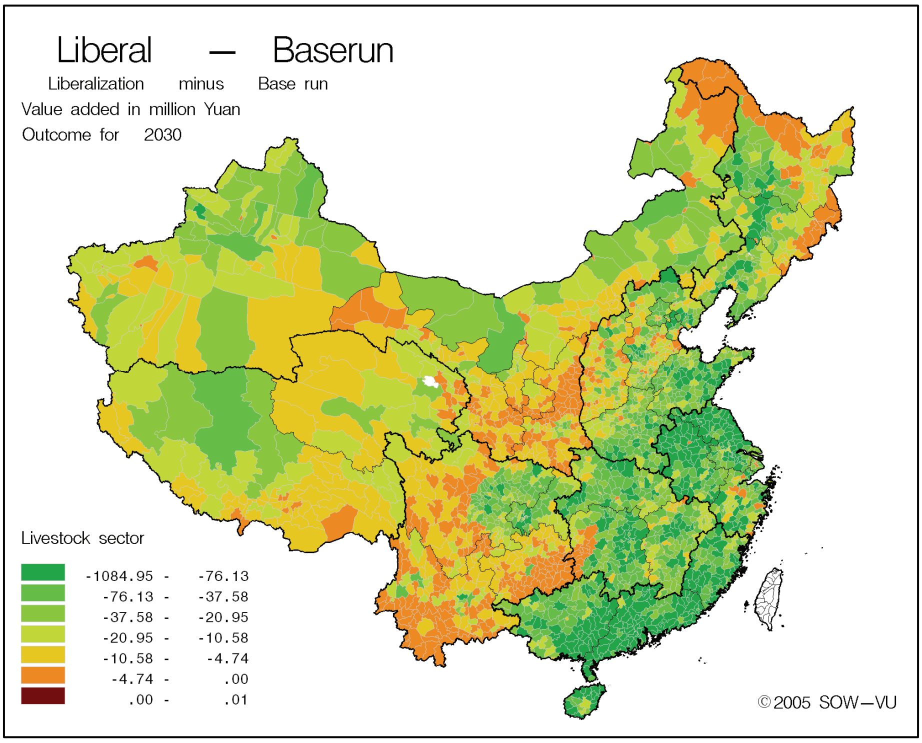


Figure 6.7 County level total farm value added: difference between Liberal and Baseline, 2030

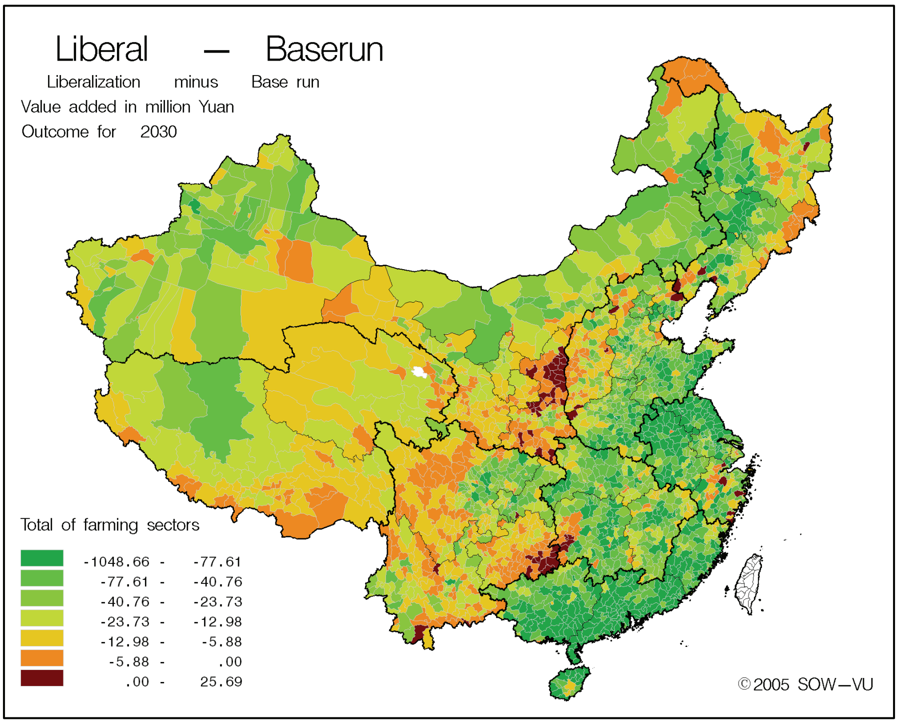
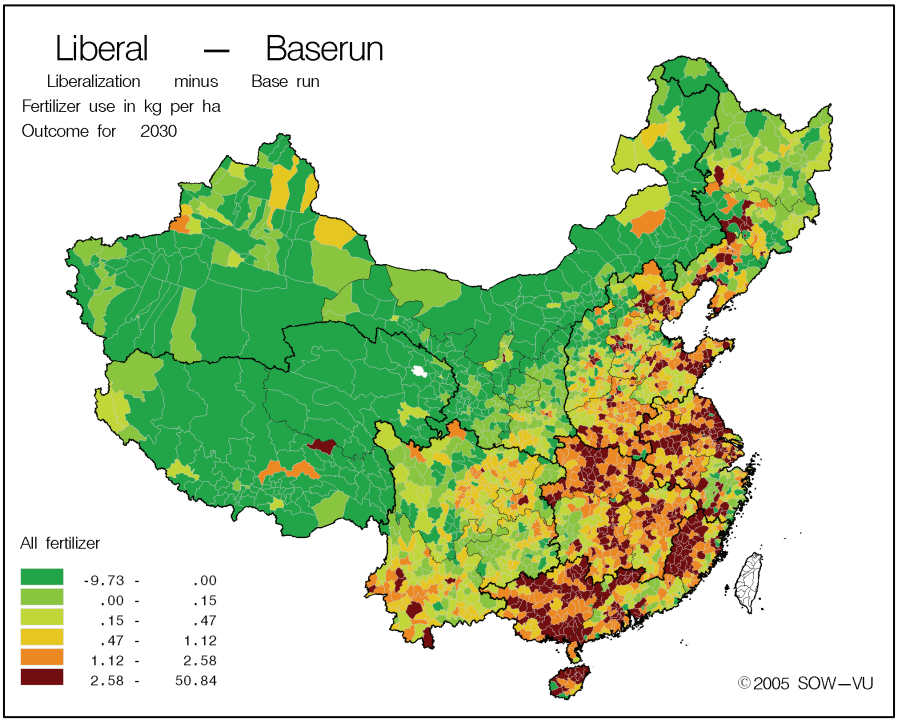


Figure 6.8 County level fertilizer use per hectare: difference between Liberal and Baseline, 2030



As far as environmental pressure is concerned, liberalization has not much effect. Feed use and, hence, production of manure decrease somewhat (Table B.3), whereas fertilizer use increases with on average 1 to 4 kg per hectare (Table B.11). Yet, as shown in Figure 6.8, the largest increases are again in counties of East, Central and South where fertilizer use is already high, thereby adding to the environmental pressure.

The effects of this agricultural trade liberalization scenario, in particular the negative effects on farm value added and the positive effects on consumer welfare, reflect the critical choice agricultural trade policies are facing worldwide in weighing economic efficiency and overall consumer interests against considerations about income distribution and poverty alleviation in the short to medium term. The lower prices that farmers face as consumers are insufficient to compensate for their loss in value added.

Yet, even though we refer to Chinagro as a general equilibrium welfare model, we should reemphasize that the results are to a significant extent partial in that they take many scenario variables as given and through this neglect various feedbacks. We did already mention the assumed non-reaction of world prices that may cause some overestimation of the effects, and the non-reaction of agricultural resources (total farm labor and equipment as well as farm land availability and stable capacities) that limits the size of the effects. Furthermore, the lower food prices could reduce the cost of living and through this promote growth, also in rural areas providing more off-farm employment to the population and allowing for rural to urban migration.

Nonetheless, we may conclude that our simulation does not support the common view that agriculture will after a transition period automatically benefit from the liberalization. Compared to other studies on trade liberalization such as Anderson, Huang and Ianchovichina (2004), Huang, Li and Rozelle (2003) and Huang and Rozelle (2003), we are less optimistic about, especially, the effects on the livestock sector in the coastal areas. On the other hand, our results are more favorable for agriculture than those of Diao, Fan and Zhang (2003) who report across-the-board decreases of about 9% in rural incomes due to the elimination of all agricultural tariffs. In all, the benefits of agricultural trade liberalization for the farm sector will greatly depend on the package of measures adopted to improve the sector's labor productivity and ecological performance that could allow expansion at higher wage rates and lower environmental costs. The success of such policies critically hinges on the extent to which the non-farm sector can absorb additional labor in and from rural areas.

6.2 High income growth scenario

Under the *high income growth* scenario, the main concern is finding out to which extent China's dependence on world food markets will increase if incomes and hence food demand grow faster than under the baseline and whether maintaining some agricultural protection is helpful in this situation. To this end, the scenario assumes higher growth rates in the non-agricultural sector, together with increased migration to urban areas and higher fertility rates. The scenario also assumes that the higher growth rate is associated to faster loss of farm land and farm labor to the urbanization process. Technical progress is faster as well. Stable capacities are kept at baseline level. The impacts are as follows.

The faster income growth and urbanization shift demand away from cereals. Per capita consumption of grain in 2030 is 151.6 kg, meat and egg intake increase to 83.6 kg and calorie intake to 2857 kcal/day, as opposed to 155.0 kg grain, 77.0 kg meat and eggs, and 2828 kcal/day in the baseline (Table B.4). Combined with the faster technical progress, and in spite of the loss of farm land, the shift in demand leads to higher rice exports: 8 million tons in 2030 as opposed to 4.3 under the baseline. For wheat the demand reduction causes domestic prices to be about 5 percent lower in 2030 but this still is too high for wheat exports to become profitable (Tables B.1 and B.5). Because of increased demand not fully offset by increased production the self-sufficiency rates of vegetable oil, sugar, and fruit will be lower. In 2030, imports of vegetable oils increase by 1.0 million ton and sugar imports increase by 0.8 million tons, whereas fruit exports fall by 4.0 million ton (Table B.1).

High growth makes the livestock sector more profitable, particularly its ruminant component (Table B.6), while crop prices remain constant or even fall, as in the case of wheat due to reduction in demand. Consequently, labor shifts towards livestock where more value added can be earned (Table B.7). Total farm GDP is higher than that under the baseline. Table B.8 shows an increase of livestock value added of 153 billion Yuan and a decrease of cropping value added of 51 billion Yuan in 2030, making the livestock sector even larger than cropping. Yet, due to the reduction in farm labor input, income per worker grows also in the cropping sector faster than under the baseline, viz. 3.7% annually compared to 3.6% under the baseline. For livestock the annual growth rate becomes 5.1%, against 4.7% under the baseline (Table B.10).

However, because the scenario keeps the international prices and stable capacities the same as in the baseline, while farm labor availability becomes less, the positive effect on livestock output is modest and so is the effect on feed imports: the scenario essentially by construction supposes that because of the favorable employment opportunities outside agriculture and the already existing environmental pressure in densely populated areas, additional demand for livestock products does not trigger much increase in domestic production. Therefore, the demand increases are largely met by additional meat imports, as shown in Table B.2. Meat imports in 2030 now also comprise ruminant meat (0.7 million ton), while pork imports increase from 6.2 to 9.7 million ton, and poultry meat imports from 2.9 to 5.1 million ton. Milk imports shift from 28.9 to 39.8 million ton. As domestic meat production does not rise much, feed imports are only little higher: maize 2%, carbohydrate feed 10% and protein feed 3% (Table B.3).

The 2030 agricultural trade deficit increases significantly from 28.9 billion USD in the baseline to 48.2 billion USD. Since the growth rate of non-agricultural GDP rises from 6.4% to 7.1% this would not seem to create financing problems for China but it would definitely create scarcity on world markets, and cause increases in world food prices not accounted for in this scenario.

Figure 6.9 County level crop value added:
difference between High Growth and Baseline, 2030

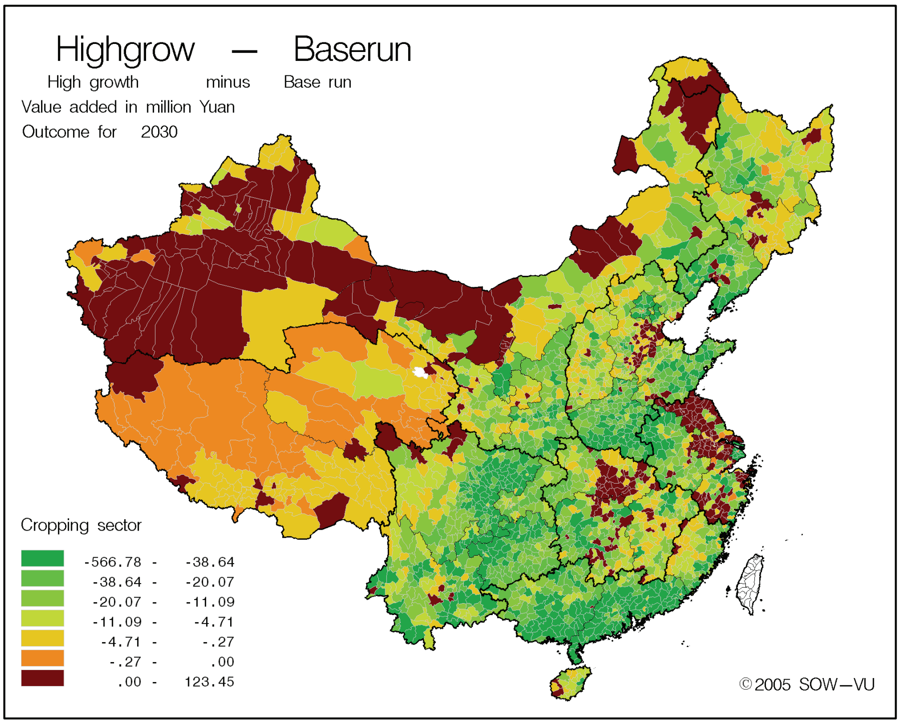


Figure 6.10 County level livestock value added:
difference between High Growth and Baseline, 2030

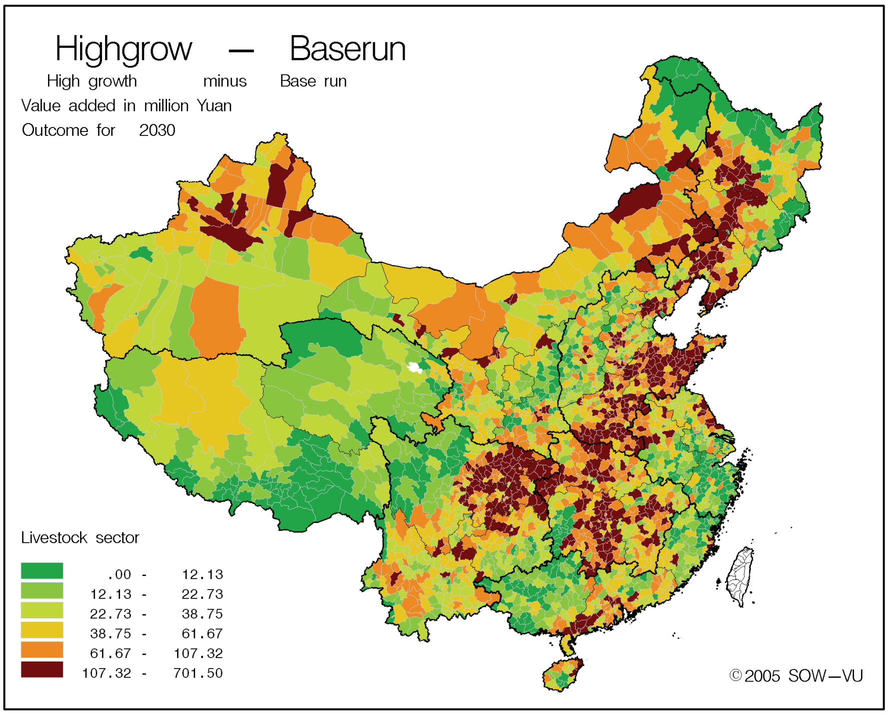


Figure 6.11 County level fertilizer use per hectare: difference between High Growth and Baseline, 2030

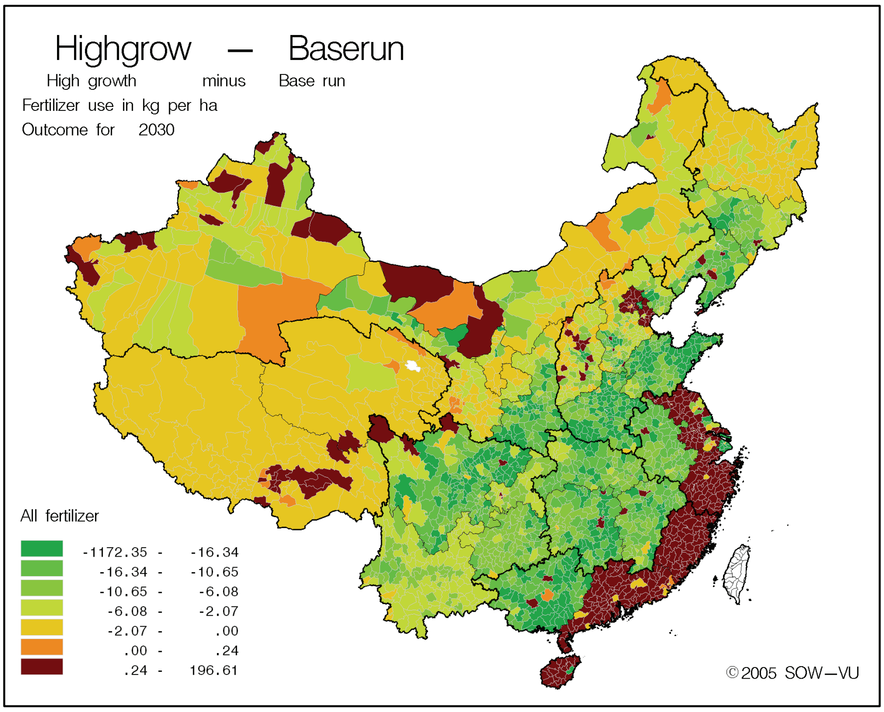
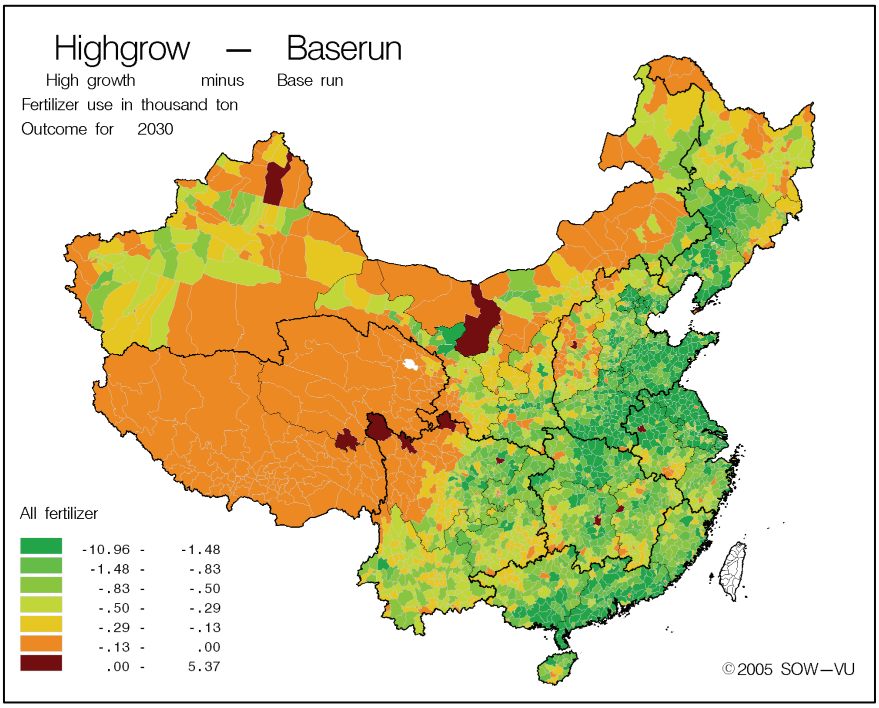


Figure 6.12 County level total fertilizer use: difference between High Growth and Baseline, 2030



Geographically, the decreases in crop value added are distributed rather uniformly over the regions (Table B.9). The same applies to the increases in livestock value added, albeit that East and South benefit somewhat less than the other regions that either have a larger share of ruminants or are inland areas. Inland areas gain more from white meat price increases than coastal areas where the possibility of direct foreign imports tends to keep these prices closely tied to the world price. The distribution of the changes in value added over the counties is shown in Figures 6.9 and 6.10, for crops and livestock, measured in millions of Yuan difference in 2030 compared to the baseline. For crops, we note that value added is not decreasing everywhere. There are counties in which it is higher than under the baseline. This can be attributed to a slight rise of the price of vegetables for which the export constraints become less tight, due to the increased domestic demand. However, such improvements are modest and visible only in counties where wheat output is relatively unimportant. For livestock, the map offers an illustration of the earlier conclusion from Table B.9 that, with few exceptions, the counties with highest increases are not located in the coastal regions East and South.

The shift in labor away from the crop sector causes chemical fertilizer use per hectare in 2030 to drop from 376 kg in the baseline to 366 kg, amounting to 2.7 per cent decline in total, and the total fertilizer use, organic as well as chemical, declines from 450 kg to 439 kg (Table B.11). Together with the reduced availability of arable land due to urbanization, this leads to a somewhat lower use of fertilizer, especially of chemical fertilizer that in 2030 drops from 43.8 to 42.0 million ton, a 4.2 percent decline (Table B.12). The distribution of the changes over the counties is shown in Figures 6.11 and 6.12, for all fertilizer taken together (chemical plus organic), measured respectively in kg per hectare and thousand ton. The map confirms that absolute levels of fertilizer application decline throughout the country, excepted some scattered counties inland. However, the application per hectare is not declining everywhere, and particularly not in the densely populated coastal provinces of East and South where a reduction would be welcome as environmental pressure is already high under the baseline. The fertilizer intensification in these regions is also coupled to increased labor-substituting mechanization.

The other aspect of pollution we report on, pollution from livestock, is directly related to feed intake. In general, changes are modest, as observed in the discussion of Table B.3. Therefore, we may conclude that growth outside agriculture and faster technical progress only make a modest contribution to alleviation of environmental pressure in agriculture.

To sum up, the higher income growth scenario does not create major problems for food self-sufficiency or the environment. The scenario assumptions about stable capacities might, however, be on the conservative side. Assuming higher growth in these capacities would lead to substitution of meat imports by feed grain imports. Farmer incomes in the livestock sector would be higher, but environmental pressure also.

6.3 High R&D scenario

In the baseline outcomes two issues come to the fore as problematic. The first is that the income gap between agriculture and non-agriculture is mounting, especially for crop farmers and less for livestock farmers, when measured in terms of farm value added per worker, recalling that our calculations say nothing about family income that could include off-farm earnings. The second is the increasing environmental pressure, especially in densely populated areas. Another salient feature of the baseline outcomes, albeit less problematic, is that the agricultural trade deficit is rising fast in response to the increasing demand for livestock products, too fast to be offset by higher exports from horticulture. Can faster technical progress help in these respects? This is the question addressed by the *high R&D* scenario that assumes higher Solow-neutral technical progress in annual cropping, in pork and poultry production and in the specialized dairy sector, as well as improved efficiency in fertilizer use. Total factor availability, urbanization, growth outside agriculture and international trade conditions are kept as in the baseline.

It appears that additional technical progress leads to higher output, as could be expected, especially of commodities that can remain in a stable import or export regime. For other commodities, such as those in autarky, a drop in price occurs that incites farmers to substitute away from them. Among the crop commodities, vegetable oil, maize and rice show the largest growth, ending up in 2030 respectively 9.8%, 9.3% and 8.4% higher than under the baseline (Tables B.1 and B.3). Among the livestock commodities, pork benefits most, with a 5.4% higher output in 2030 (Table B.2). To put these rates into perspective, without substitution the output of annual crops would be 6.8% higher and the output of white meat 5.1% higher than under the baseline. Figures 6.13 and 6.14 show how the additional output of rice and poultry meat is distributed over the counties, measured in thousand ton difference with respect to the baseline. It appears that the distribution of these increments closely follows the projected baseline production patterns.

Food consumption is not changing much since in this scenario there is no change in non-agriculture income and urbanization. Consequently, supply changes are absorbed largely by foreign trade, as shown in Tables B.1 – B.3. Exports are higher in 2030, especially for rice: reaching 15.6 instead of 4.3 million tons under the baseline. For fruits 6.4 instead of 4.7 million tons are exported, and for vegetables 15.4 instead of 13.3 million tons, the latter reaching now nationwide the export quota imposed in the scenario to avoid deterioration of world prices. Imports of both food and feed are lower in 2030. For instance, maize 11.1 instead of 22.0 million tons, vegetable oil 8.2 instead of 9.1 million tons, sugar 2.4 instead of 3.1 million tons, pork 4.0 instead of 6.2 million ton, carbohydrate 37.0 instead of 56.6 million gcal, and protein feed 97.7 instead of 113.6 million gcal. Milk imports are lower as well in 2030 but compared to the total volume the difference is small: 27.8 instead of 28.9 million tons. Overall, the higher technical progress reduces the 2030 agricultural trade deficit from 28.9 billion USD to 13.4 billion USD. This reduction reflects the overall increase in self-sufficiency in food and feed.

With respect to farm incomes, outcomes are less favorable than might be expected on the basis of the output increases. Cropping value added only reaches 1,565 billion Yuan by 2030 (Table B.9), against 1,526 billion Yuan in the baseline, hence an increase of 2.6% whereas an increase of around 6% could be expected on the basis of the scenario assumption of 0.2% higher annual productivity. This happens because half of the gains end up with the consumers, due to lower prices of, especially, wheat and vegetables (Table B.5). The livestock sector does not face such price decreases and is, therefore, able to retain most of its productivity gains: its value added in 2030 is 1,387 billion Yuan which is 3.5% more than in the baseline, only slightly less than the output increases. Similar increases are obtained for the value added per worker (Table B.10) since the allocation of labor to crops and livestock adjusts only marginally.

Figure 6.13 County level rice production: difference between High R&D and Baseline, 2030

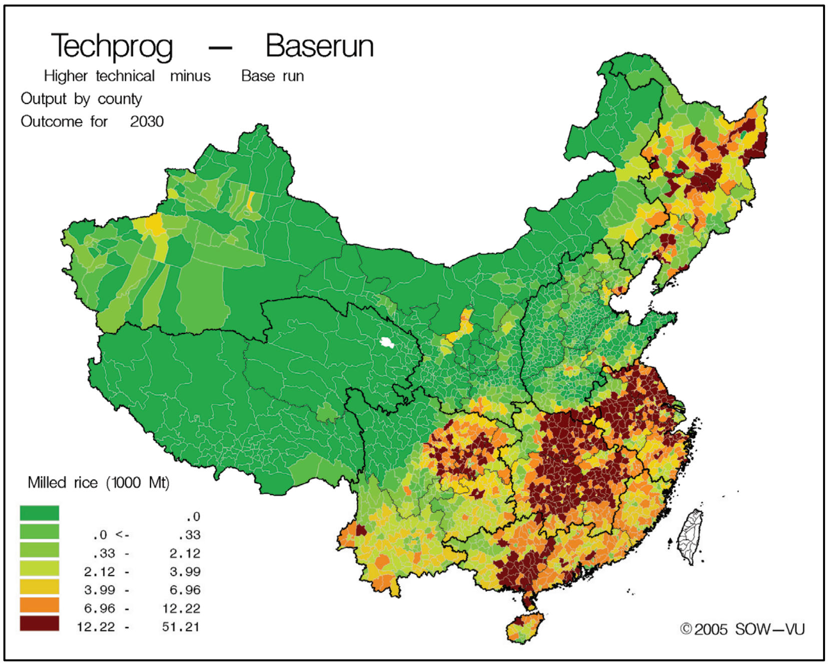


Figure 6.14 County level poultry production: difference between High R&D and Baseline, 2030

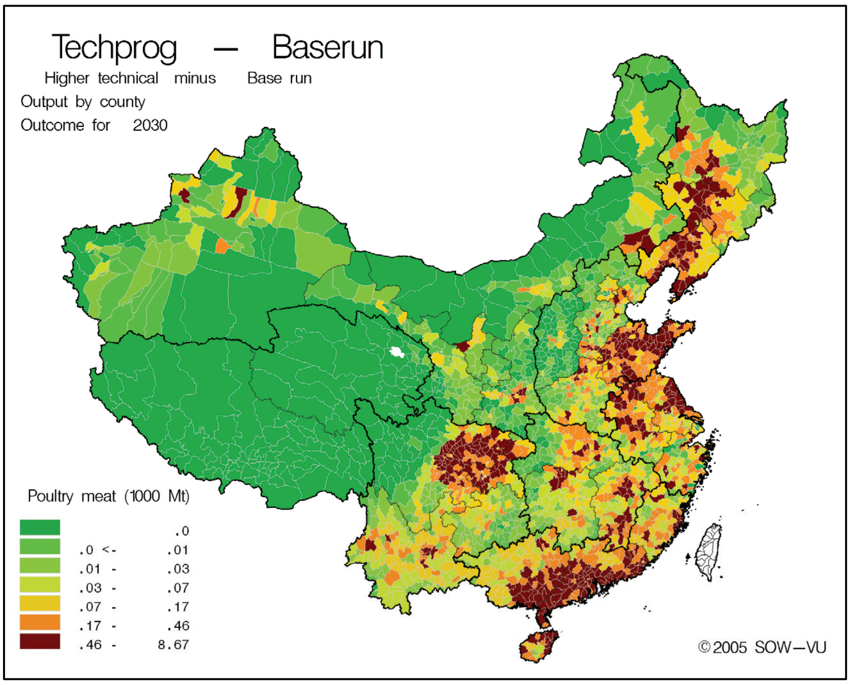


Figure 6.15 County level crop value added:
difference between High R&D and Baseline, 2030

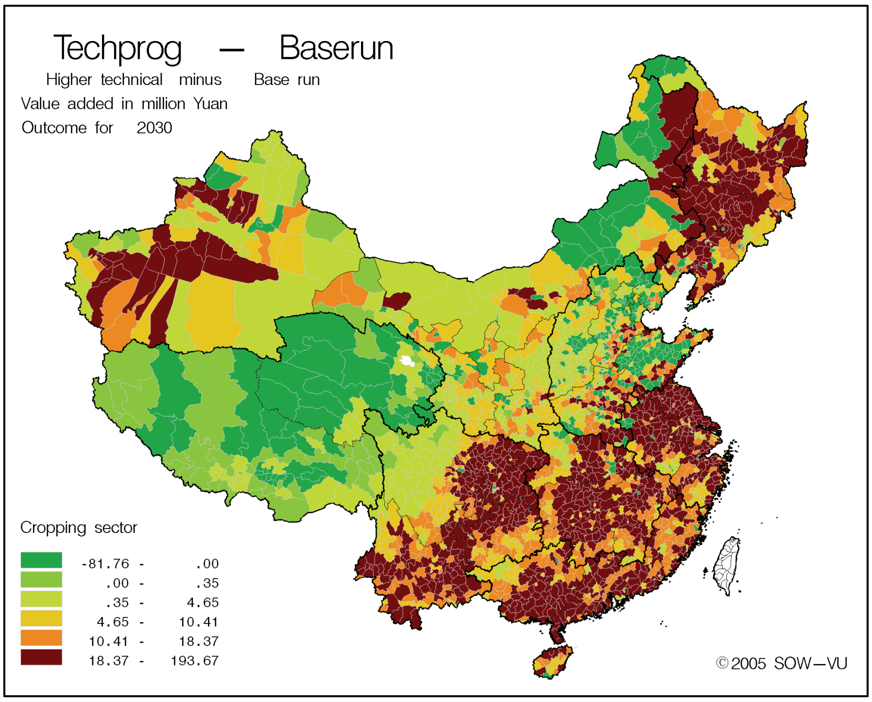


Figure 6.16 County level livestock value added:
difference between High R&D and Baseline, 2030

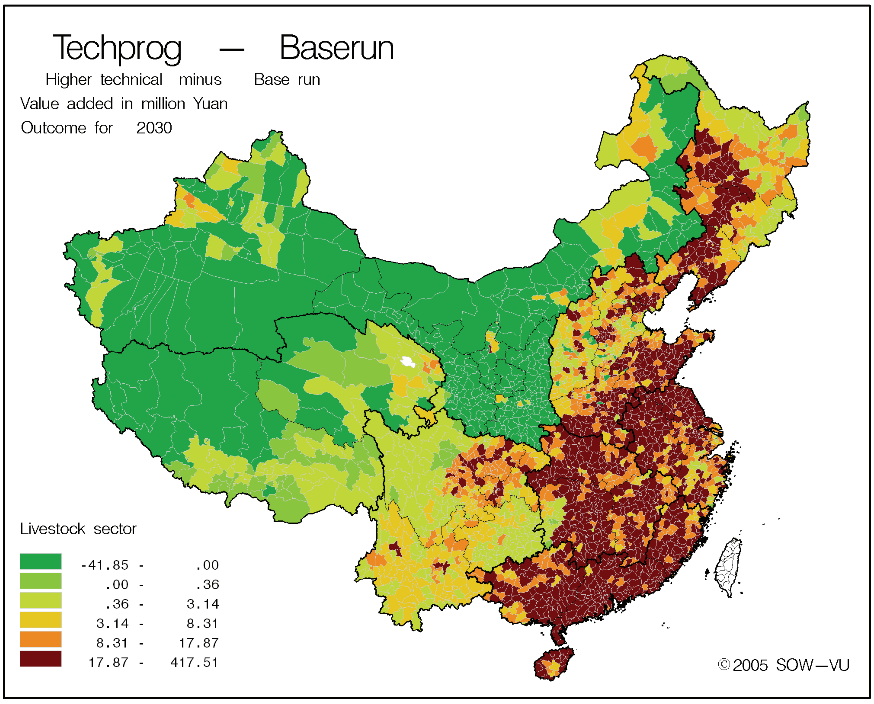


Figure 6.17 County level fertilizer use per hectare: difference between High R&D and Baseline, 2030

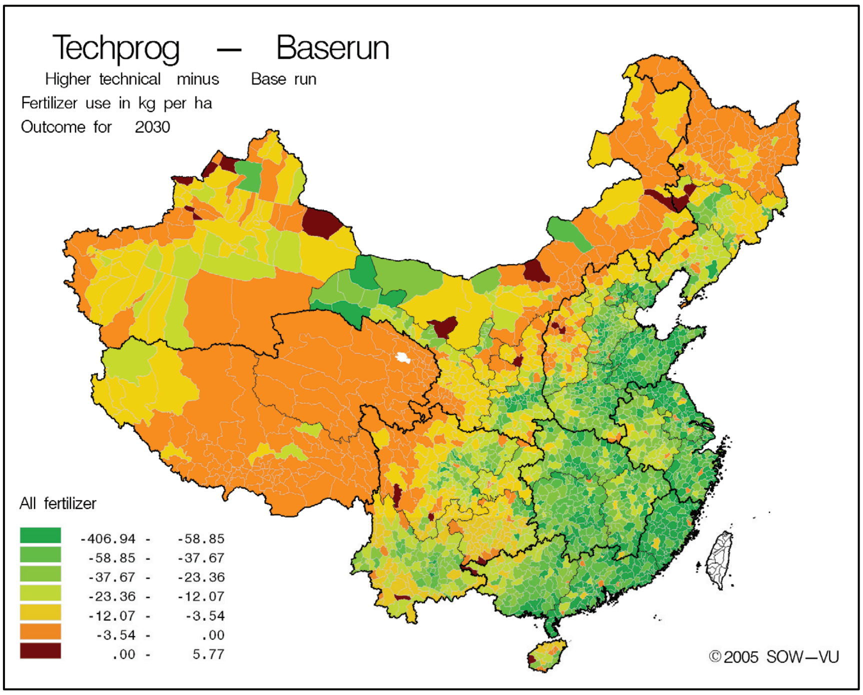
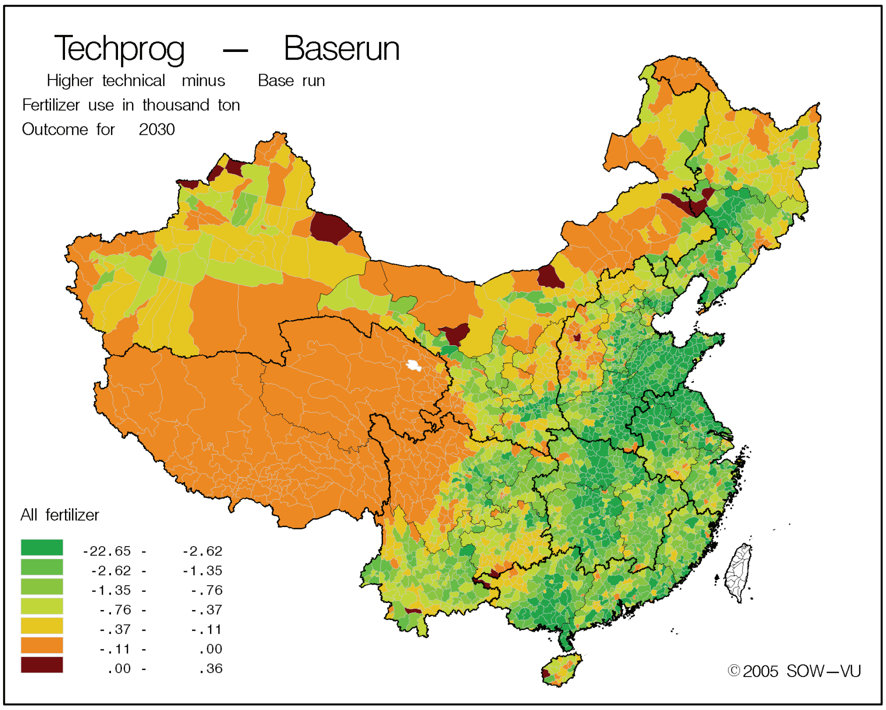


Figure 6.18 County level total fertilizer use: difference between High R&D and Baseline, 2030



The distribution of the increases in value added is shown in Figures 6.15 and 6.16 for crops and livestock. Almost all counties in Northeast, East, Central, South and Southwest benefit from the boost in technical progress but there are also counties that lose income, especially in North, Northwest and Plateau. These are counties that suffer from the price reduction of wheat and vegetables and those that do not benefit much from the assumed technical progress since they depend more on orchard land, traditional livestock and grazing ruminants.

Regarding the environment, the scenario assumes an increase in the efficiency of fertilizer use, with 0.5% per year. This leads to lower amounts of chemical fertilizer use per hectare: 510 kg per hectare on irrigated land and 195 kg per hectare on rain-fed land in 2030, compared to 559 and 207 respectively in the baseline. The average level becomes 346 kg per hectare as opposed to 376 in the baseline (Table B.11). The rate of reduction of fertilizer use is lower than the technical progress would allow at the same yield, since the farmers react to the gain by applying more fertilizer so as to raise the yield. The largest reductions, both in terms of application per hectare and in absolute amounts, are found throughout the coastal areas and the Central region, hence in the areas with the highest environmental pressure (Figures 6.17 and 6.18). With respect to emissions of pollutants from livestock production, we observe that the scenario assumes no specific increase in feed efficiency (only Solow-neutral progress in the livestock sector) and keeps stable capacities unchanged. Therefore, overall feed intake hardly changes (Table B.3) keeping the production of manure close to baseline level as well.

In summary, the technical progress scenario indicates that higher R&D expenditures will indeed reduce China's reliance on the international food and feed markets significantly and relax the environmental pressure somewhat (provided that the expenditures lead to the order of magnitude of technical progress assumed by the scenario), but in terms of farm incomes the improvement is minor and the gap with non-farm income hardly diminishes.

In the present scenario, world markets are supposed to absorb most of the additional farm output and through this they enable Chinese farmers, in terms of value added per farmer, to maintain a large part of the gain from productivity increases. However, farmers also depend on goods that are not exported, and the mechanism causing the limited impact of technological intervention is that for commodities in autarky a rise in farm output triggers a price reduction that shifts part of the benefits to the consumers. This mechanism is well known and points to the classical problem facing agricultural policy makers worldwide that, unless the market can absorb additional output, demand remains inelastic and technical progress in farming goes to a significant extent at the expense of farmers themselves. Farmers are in this respect very different from high-tech companies that engage in R&D but reap the fruits through patents and (temporary) monopolies. Indeed, short of resorting to protectionism, in agriculture policy makers eager to supply the cities with ample food at affordable prices do not have too many options available, which generally have to be pursued simultaneously. One is promoting labor outmigration from agriculture into off-farm employment, so as to reduce the number of people dependent on farm value added, and to add non-farm income to family income. At the same time the outflow, when sufficient, makes it possible for farmers to increase in farm size and engage in mechanization, possibly with improved financial intermediation. Another parallel option is to help product differentiation with a focus on improved qualities for market segments that are willing to pay for it. Clearly, improvements of trade and transport infrastructure and of competition among intermediaries will help reducing the income gap. R&D has an important role to play in this context, but only as part of a wider package, as the present scenario has illustrated. A final element in such a package is improved irrigation, which stands for a general improvement of the resources in farming. The next section reports on a scenario with enhanced irrigation.

6.4 Enhanced irrigation scenario

Much like the high R&D scenario, the *enhanced irrigation* scenario aims at raising farm incomes and reducing the country's agricultural trade deficit by improving the conditions under which farmers can operate. However, the difference is that irrigation is more location-specific. Hence, the improvements are less evenly distributed across counties than under the high R&D scenario, which means that deprived counties will lack opportunities to compensate for falling crop prices. With respect to environmental pressure, the outcomes are rather predictable in this scenario since more fertilizer is applied on irrigated land than on rainfed land, whereas livestock manure production will not change much as stable capacities remain unchanged.

The scenario assumes that part of rainfed land is shifted to irrigated land whereas total cropland remains the same in each province. In all, some additional 5.6 million hectares are irrigated in 2030 as compared to the baseline, which amounts to 10% of total irrigated area. The differences are specified by province, with, compared to the 2030 baseline levels, the largest relative additions in the Northeastern provinces with 22%, followed by the Central and Northwestern provinces with 12%. Less spectacular expansions are considered feasible in the provinces of North (except Beijing), East (except Shanghai), South and Southwest with 7.2%, and only limited increases are assumed for Beijing, Shanghai, Tibet and Qinghai with 2.4%. This geographical distribution further builds the large irrigation potential of the Northeastern provinces, already present in the baseline specification. Furthermore, since irrigated land requires more labor and machinery per hectare, the scenario also imposes compensating resource shifts to avoid shortages and keep aggregate yields (in terms of dry matter per hectare) the same as in the baseline, on both rainfed and irrigated land. All other elements of the baseline scenario remain unchanged. We should emphasize that this assumption also applies to international trade, making large changes in China's exports possible at the same exogenous world price for all commodities except vegetables. We return to this point later on.

In terms of output, the simulation not unexpectedly generates a shift towards the crop-mix prevailing on irrigated land. At national level the main effects in 2030, compared to the baseline, are (Tables B.1 and B.3) a rise in rice production of 15.4 million ton (11%), wheat 1.8 million ton (2%), maize 1.7 million ton (1.5%) and vegetables 3.5 million ton (1.2%). Furthermore, the supply of composite feeds expands, especially for protein feed (4.5%), due to additional availability of rice bran. Output diminishes for 'other staple' (minor grains, root crops, soybeans, groundnuts), in total with 1.1 million ton of soybean equivalent (5%), as well as for sugar with 0.3 million ton (2.5%) and fruits with 1.5 million ton (2%). As in the high R&D scenario, for wheat and vegetables output rises are dampened by price falls (Table B.5). Without substitution, wheat would have gone up with 4.1 million ton. The other two major grain commodities benefit from the substitution process. Maize would have declined even by 0.3 million ton. Output of the livestock sector is hardly affected in this scenario (Table B.2).

Figure 6.19 County level rice production:
difference between Enhanced Irrigation and Baseline, 2030

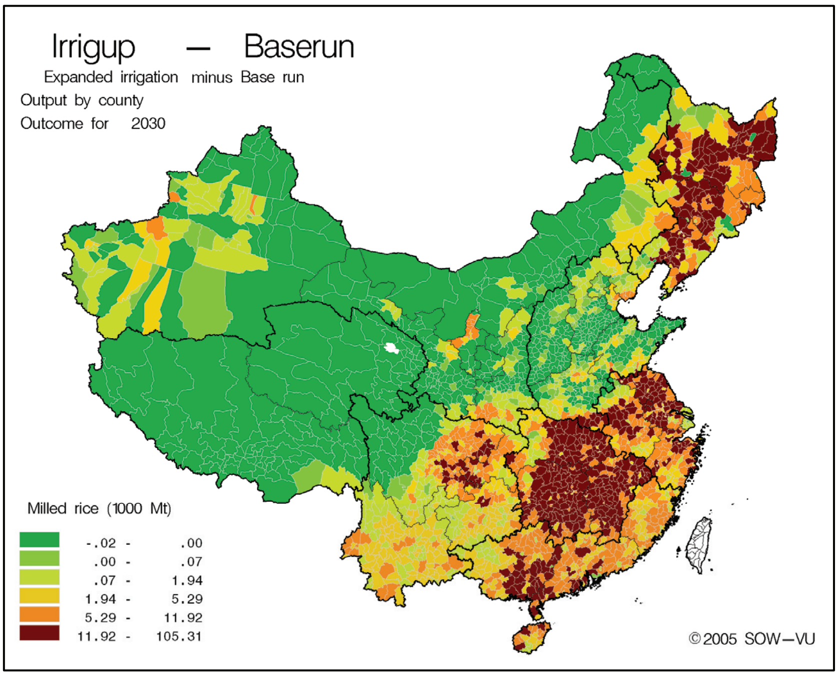


Figure 6.20 County level wheat production:
difference between Enhanced Irrigation and Baseline, 2030

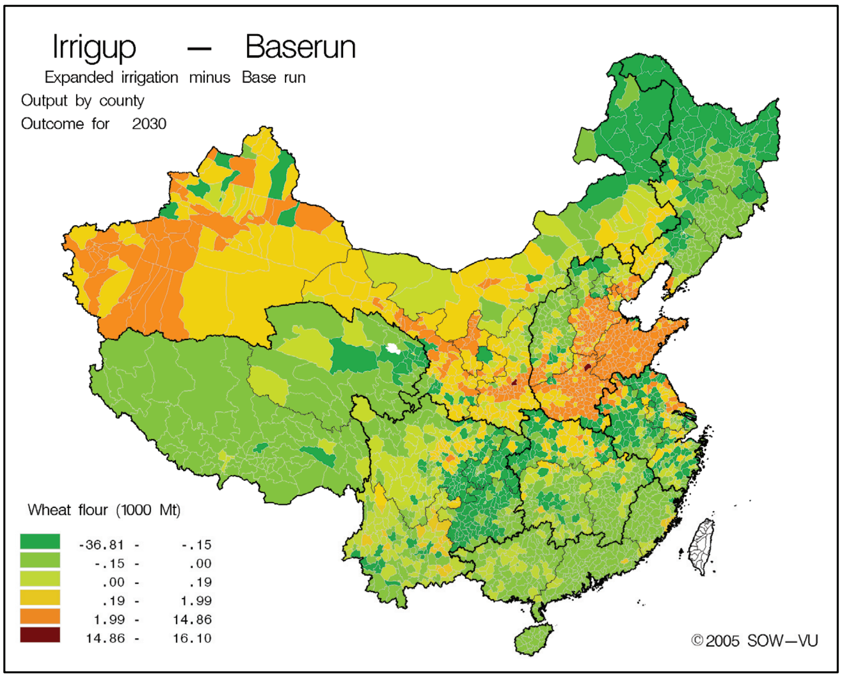


Figure 6.21 County level maize production:
difference between Enhanced Irrigation and Baseline, 2030

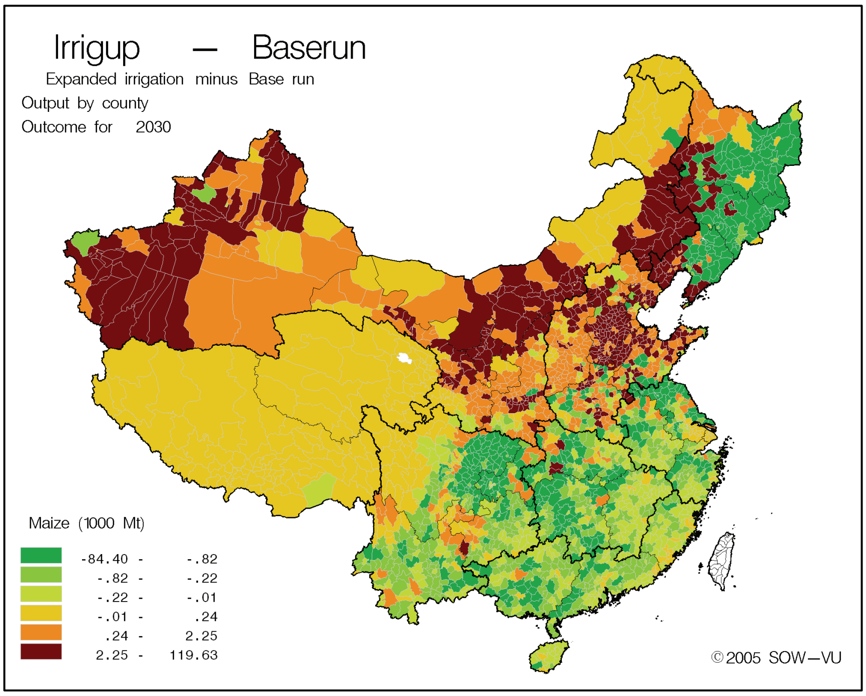
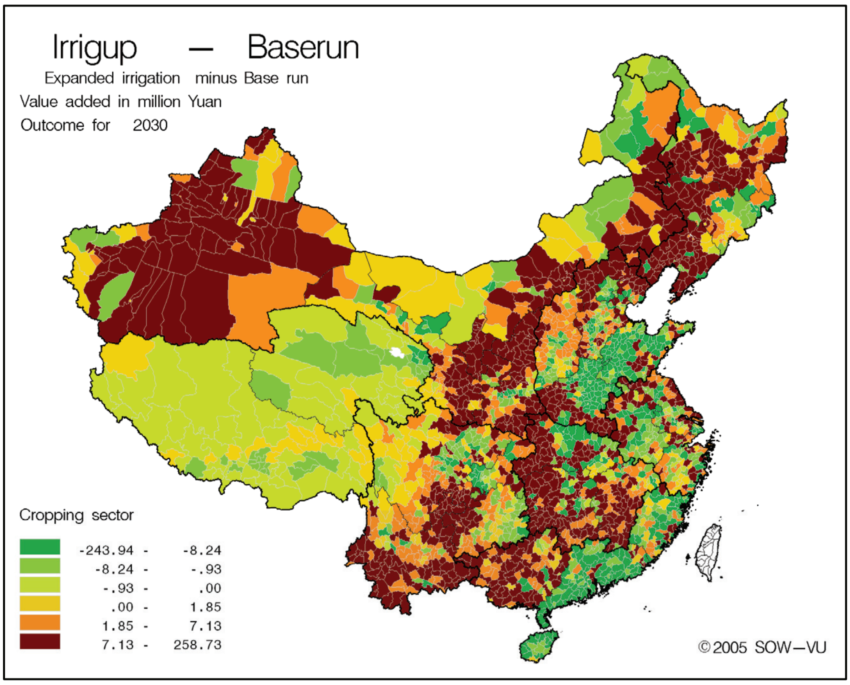


Figure 6.22 County level crop value added:
difference between Enhanced Irrigation and Baseline, 2030



Regionally, the changes in grain supply can be summarized as follows. Rice, almost exclusively grown on irrigated land, expands everywhere, with the largest relative increases in Northeast, Central and Northwest, hence following the area shifts specified in the scenario. Figure 6.19 shows the absolute changes by county in 2030, measured in thousand ton difference with respect the baseline. Indeed, also in absolute terms the largest increases are found in Northeast and Central but not in Northwest, which is a minor producer. Wheat, largely grown on irrigated land, goes up in North, Northwest and South but decreases elsewhere, due to its fall in price. Figure 6.20 details these outcomes at county level. Maize, grown on irrigated and rainfed land, is on the rise in North and Northwest, and contracting in the other regions, as illustrated in Figure 6.21.

With respect to the potential of the North China Plain to become a major feed producing zone, one of the key questions raised in section 2, we observe that in this scenario, by 2030, the conversion of 1.1 million hectare rainfed land into irrigated land generates significant increases in feed supply, including 1.4 million ton maize, 0.4 million gcal carbohydrate feed and 1.8 million gcal protein feed. Yet, this is not enough to keep North in a net maize exporting position beyond 2010. Maintaining this position would require a larger volume of land conversion or higher feed prices.

In the absence of price effects, the output shifts would lead to an increase in crop value of about 30 billion Yuan in 2030, whereas expanded irrigation causes an increase in use of chemical fertilizer by approximately 2 million ton in 2030, amounting to an additional application of 350 kg/ha on 5.5 million hectare, with a value of 5 billion Yuan. Thus, a rise in cropping value added of about 25 billion Yuan would result, relative to the baseline. However, crop farmers fall in the same 'sales trap' as in the high R&D scenario, with price drops for wheat trapped in autarky and for vegetables trapped at upper bounds on regional exports. Consequently, a substantial part of the gain in cropping value added vanishes to the benefit of consumers, leaving 12.5 billion Yuan for value added (Table B.8).

Table B.9 shows that from a regional perspective net changes in value added are not everywhere positive. In particular, they are negative in North, South and Plateau that apparently suffer more from the price falls than they benefit from the expanded output. For North and Plateau this is due to the dominance of wheat and vegetables. In South that hardly grows wheat the negative sign can only come from vegetables, but the relatively small difference in value added per hectare between irrigated and rainfed land also helps explaining the result. Figure 6.22 shows the county distribution of the absolute differences in value added with respect to baseline, measured in million Yuan, and reflects the signs at regional level.

In this scenario the environmental pressure from fertilizer use increases. For the country as a whole, the average application of chemical fertilizer reaches 395 kg per hectare in 2030, as opposed to 376 kg per hectare in the baseline. The trend is the same in all regions (Table B.11). As mentioned already, this is a rather direct consequence of the scenario.

The lower prices of wheat and vegetables lead to an increase in per capita consumption in 2030, from 55.7 to 56.8 kg and from 163.3 to 164.6 kg, respectively. Consumption of other commodities is hardly affected as exports absorb the rise in supplies, particularly for rice. Hence, the agricultural trade deficit in 2030 drops to 24.2 billion USD, as compared to 28.9 billion USD in the baseline.

In short, enhanced irrigation improves consumer welfare and the agricultural trade balance but this abstracts from the cost of the investments in irrigation, which are not shown explicitly. The simulation also finds a limited and sometimes negative effect on farm incomes, due to price reductions. Furthermore, the environmental pressure mounts further. Hence, like technical progress, irrigation can contribute to agricultural development but needs to be matched by accompanying measures to compensate farmers in negatively affected areas.

Finally, with respect to scenario specification, the resulting amount of rice exports (almost 20 million ton in 2030) can arguably not be realized without lowering the world prices, if exportable at all. It might, therefore, be more realistic to impose export bounds as for vegetables. However, this would not change the main sense of the results as it would shift even more benefits from farmers to consumers. Another objection to the model outcomes could be that the assumed degree of substitution among crops is too low[33] and that farmers will be able to maintain a larger part of the irrigation benefits by switching faster to other crops. This would need further empirical testing.

[33] In the current specification of the Chinagro model, the substitution elasticity among crops, based on empirical simulation exercises, is 0.6 on irrigated as well as on rainfed land.

7. Summary and policy implications

This report has described prospects and challenges for Chinese agriculture until 2030 under different scenarios, using the Chinagro welfare model. We recall that a scenario, rather than referring to a set of purely exogenous assumptions, is defined as a coherent set of assumptions about exogenous driving forces (farm land, population, non-agricultural growth, world prices etc.), derived from the literature and own assessments.

Under these assumptions, simulations with the Chinagro model analyze the price-based interaction between the supply behavior of farmers, the demand behavior of consumers and the determination of trade flows by merchants. For each scenario the simulations result in a consistent set of outcomes for the endogenous variables such as market prices, farm output and input volumes, food intake and domestic and foreign trade flows. In addition to the baseline scenario, four variants have been analyzed: trade liberalization, high income growth, high R&D spending and enhanced irrigation. We summarize the main findings for each of these, reiterating that the baseline scenario assumptions, although exogenous in the model, can to a large extent be interpreted as findings, in the sense that they distill an integrated perspective on future developments from the literature available. Our summary relates to prospects, policy challenges raised and topics for further research.

Likely future trends of exogenous driving forces

On the demand side, we envisage the following trends in demography and lifestyles:

- China's population will grow to about 1460 million people in 2030, which is 15% higher than the 2000 level. In absolute numbers this implies a growth of 190 million people in 30 years, only around 40% of the increase that has occurred during the previous 30 years, from 1970 to 2000.
- Important changes in lifestyles are expected to result from income growth and urbanization. We project the level of urbanization to reach around 60% in 2030, compared to 36% in 2000. This means that the urban population, totaling 460 million in the year 2000, will almost double in three decades. With a projected average annual non-agricultural GDP growth of 6% to 7%, per capita incomes will increase at least fivefold. These changes in income and urbanization will have profound impacts on demand structure and levels.
- Total human consumption of cereals is projected to remain close to current levels, due to two factors. First, food energy consumption levels are already high and wealthier consumers tend to replace staples by higher value foods such as livestock products and vegetables. Second, urban consumers have lower per capita consumption levels of cereals than rural people, implying that urbanization will result in overall lower average per capita consumption of cereals.
- While urbanization is slowing down cereal consumption, it will likely accelerate the increases in meat consumption that result from higher incomes. Urban diets include higher consumption of meat than rural diets and per capita meat consumption is responding strongly to income growth. We project consumption of livestock and fish products to double almost. At the projected level of per capita consumption, urban China would in 2030 (with 75 kg meat and 27 kg eggs) be approaching the current levels of industrialized countries. Also dairy consumption rises fast, reaching 62 kg of milk equivalent per urban inhabitant in 2030, as opposed to only 7.5 kg in rural areas.

On the supply side, we see the following prospects for agricultural resource availability and technical progress:

- 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 between 2000 and 2030, i.e. 5% to 7% of its 2000 size. The effect will be much larger for the South and the East regions, with decreases of at least 10% and 15%, respectively.
- We expect that, despite current legislation and policy efforts, 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 (excluding orchard land) would be in the range of 115 to 117 million hectare, hence significantly lower than the 128 million hectare in 2000.
- Irrigation water is essential for China's high grain output from limited farmland. Currently, almost all rice, more than 80% of wheat and 45% of maize are grown on irrigated land. We project the share of irrigated land to increase slightly between 2000 and 2030, from 47% to 48% of annual cropland, mainly due to expansion in the Northeast. However, with additional efforts a higher increase would be possible, up to over 50%.
- Intensified livestock systems will play the leading role in meeting the increased demand for meat in the future. Pig, broiler and layer stocks in intensified systems are expected to increase on average at least 2.5 times between 2000 and 2030, with a geographic distribution across counties largely reflecting population density.
- With respect to ruminants, pastoral livestock will grow much less than confined livestock. For grazing herds, we project an estimated growth of around 20% between 2000 and 2030, whereas the stock of confined ruminant meat cattle is foreseen to double and the stock of specialized dairy to become even 5 times as large, while for large animals used for work and transportation a reduction of close to 40% is foreseen.
- Even after the yield increases of the last decades, significant technical progress seems feasible. Although hard to quantify, steady yield increases of about 0.5% annually in cropping and ruminant farming and of even 1% in pig and poultry may be attainable, with sufficient levels of R&D financing and effective implementation.

Finally, with respect to agricultural market developments, we have projected the following trends for world prices and government policies:

- Considering the whole period until 2030, international agricultural prices are assumed to show a steady decline compared to the high levels reached at the end of the twentieth century. However, world prices for agricultural products are known to be relatively volatile, as illustrated by the overall price fall in 2000-2003 with recovery after 2003 that is currently turning into a price upsurge for grain and dairy, partly for structural reasons including the demand for meat and feedgrains by China itself and the emergence of biofuels, partly for transient reasons such as droughts and crop failures.
- The agricultural trade policies of Chinese government are expected to follow a path of steady general reduction of tariff rates and non-tariff barriers, leading to effective tariff rates being halved in the period 2000-2030. Similar reductions are projected for domestic producer taxes, including prevailing local fees.

Prospects under baseline

The baseline scenario simulations seem reassuring with respect to the size of foreign import requirements that remain moderate relative to China's size, though large when looked at from the world market. It would be possible to feed people as well as animals without excessive imports. In fact, the trade in food and feed between China and the rest of the world will most likely be a busy two-way traffic since, in close match with feed and meat imports, China has the potential to export large amounts of fruits and vegetables. Although its agricultural trade deficit will rise, the deficit is very minor as a fraction of total exports. Major concerns would rather be the development of agricultural value added per farm inhabitant that, although steadily increasing, stays behind per capita value added outside agriculture in all regions, the continuing disparity in per capita incomes across regions and the environmental pressure from fertilizer losses and unused manure surpluses that are currently already high in densely populated areas and will not diminish. More specifically, we may summarize the outcomes of the baseline simulation as follows:

- Most food can be produced domestically in the coming thirty years, but the country will have to import large amounts of animal feeds. These feed imports are significant on the world market but not excessive as share of domestic use in China. The shift to intensified sectors, the steady rate of technical progress and the continued important contribution of local feed sources keep the increases in commercial feed demand moderate compared to the rise in meat output.
- The country will remain largely self-sufficient in food grains. Wheat will be in autarky, whereas for rice there will even be 4 million ton exports by 2030. To achieve this, disregarding the steps to assure recovery after the output dip of 2003, no dramatic measures to augment supply will be called for.
- Feed imports grow steadily, reaching in 2030 shares of 16%, 17% and 35% of domestic use for respectively maize, carbohydrate and protein feed. The amounts concerned are significant on the world market: 22 million ton maize, 17 million ton grain equivalent, and 38 million ton cake/bran equivalent.
- For meat, import requirements are initially negligible, largely thanks to China's comparative cost advantages in livestock production. However, through its assumed trends on stable capacities the scenario simulation sees such comparative advantages weaken gradually, following changes in relative prices of major production factors and the increasing environmental pressure caused by intensive livestock production. This causes white meat imports to rise, especially after 2020, reaching 6 million ton pork (10% of consumption) and 3 million ton poultry meat (16% of consumption) in 2030, which, as for animal feeds, amount to significant flows on the world market.
- Exports of fruits and vegetables increase significantly (to close to 20 million ton, together), and so do imports of vegetable oil, sugar and, especially, dairy products.
- The resulting agricultural trade deficit of 29 billion US dollars (of 1997) in 2030 can easily be financed from the non-agricultural trade surplus that is currently already over 100 billion dollars and projected to become even much larger.
- Consumer welfare goes up considerably throughout the country, mainly because of exogenous scenario assumptions on income growth outside agriculture but also because food prices do not rise much, though domestically somewhat more than internationally, due to the demand pressure. The highest rates are found for meat with about 50% real price increase by 2030.
- Regional production trends to a large extent maintain the existing output distribution. As special cases, we note the increase in rice output in Northeast following enlargement of the irrigated area, the large meat output increases in South in response to the strong growth of the

urban agglomerations, and the massive increases in dairy in North, Northwest and Plateau where milk output becomes about 3 times as large, albeit starting from a low base.

- Despite the rather uniform growth rates of production across the regions, the changes in demand in response to migration and changes in life style generate significantly larger domestic trade flows and, thereby, higher pressure on the transportation system.
- With respect to domestic grain trade, the Central, Northeast and East region remain the leading sellers of rice, and the East, Southwest and North region the leading sellers of wheat. For maize, the three major exporting regions (Northeast, Northwest and North) do not expand their role as suppliers of the national market, due to the rising demand in the own region and, in Northeast, also to supply shifts to rice on newly irrigated areas. The North region even becomes a maize importer. Net exports of Northeast and Northwest stay more or less at their current levels. They remain the major maize exporting regions, especially Northeast.
- In spite of significant rise in their own output, the coastal regions North, East and South see meat inflows becoming large, with 2.0, 4.1 and 5.5 million tons, respectively, in 2030. The main domestic net sellers are Northeast and Central, with respectively 1.1 and 1.9 million tons. Considering just beef and mutton, Northwest will be the largest exporter, with close to 1 million tons in 2030.
- Value added from farming is rising, on average at a rate of 3.2% annually, whereas labor input in farming is falling, on average at 1% annually. Hence, value added per manyear is going up by more than 4% annually. While this would seem to be a fair pace, the gap with non-agriculture keeps on mounting, witness the rate of total per capita income of 6% until 2030. This tendency would seem cause of concern, especially for crop farming, whose per capita value added rises at 3.6% against 4.7% in livestock.
- With respect to interregional disparities, such concerns appear to apply to all regions: the increasing gap between agricultural and non-agricultural incomes is a nationwide problem, although, evidently, there are differences across counties within each region. Furthermore, the projected development will not reduce current differences in agricultural incomes across regions or provinces.
- Intensified livestock sectors become dominant in producing white meat and eggs, with in 2030 a share of 52% of pork output and more than 75% of poultry meat and eggs.
- Serious environmental problems may be caused by unused animal manure as well as losses in the application of fertilizer, especially in densely populated regions. Currently, the nutrient pressure is already strong in many counties, and it will not diminish in the future. Although on average the increases over time are moderate, with in 2030 per hectare of cropland about 10% more chemical fertilizer applied and 20% more manure nutrient available, the amounts are more and more concentrated in specific areas following the escalating strain on crop land, requiring further yield increases, and the intensification of livestock production.

Prospects under scenario variants
The *trade liberalization scenario* appears to hurt farm incomes and to raise the gap with non-agriculture, also because food becomes cheaper in urban areas. Thus, the scenario illustrates the difficult choice between economic efficiency and poverty alleviation that agricultural policy makers often face. In terms of national food self-sufficiency, the scenario does not give rise to concern. Environmentally, there are only minor changes compared to the baseline. We mention the following specifics:

- Liberalization stimulates foreign trade volumes, as imported commodities (maize, vegetable oil, sugar, dairy and, after 2020, meat) become cheaper and exported commodities (rice, fruits, vegetables) more rewarding. Trade volumes do not change much for commodities in autarky (wheat, eggs) in the baseline and for highly imported commodities such as composite feeds (carbohydrate feed, protein feed).

- Import volumes do not become excessive and can easily be financed. In all, the agricultural trade deficit rises a little only.
- Consumers benefit from the increased economic efficiency. Per capita meat intake becomes higher, in both rural and urban areas (with 5% and 3%, respectively, by 2030).
- The supply reactions are rather uniform across the country, since farmers respond everywhere to the changes in relative prices. However, specific local conditions with respect to trade and transport costs or substitution possibilities create differences. For example, pork production falls in coastal areas that are more under the direct influence of price reductions at the border, while it increases in more remote areas, where higher trade and transport margins isolate the farmers more from the world market.
- The overall effects on farm incomes are negative by 2030, but differ across land use types and regions. For cropping, a mixed pattern of increases and decreases results, with nationwide about the same value added as in the absence of liberalization. For livestock, the changes are mainly negative, especially in coastal regions.

The *high income growth scenario* confirms the reassuring conclusion about national food self-sufficiency that emerged from the baseline simulation. Even with higher meat demand than under the baseline, levels of imports remain manageable. Furthermore, due to better relative prices, livestock farming becomes relatively more attractive. Specifically, we observe the following:

- In response to higher prices, domestic meat output is raised by attracting more labor to the livestock sector. However, since the scenario keeps stable capacities unchanged, the output increases remain moderate. Therefore, the additional meat demand is met mainly through meat imports, whose share in domestic demand goes up from 11% to 16% in 2030, whereas the shares of feed imports in domestic demand increase only marginally.
- The agricultural trade deficit in 2030 will be about 50% higher but financing problems do not occur given the size of the non-agricultural trade surplus that is even higher than in the baseline scenario.
- In the livestock sector, value added per manyear becomes significantly higher, with on average 5.1% growth annually, instead of 4.7%, whereas it hardly increases in the crop sector, with on average 3.7% growth instead of 3.6%.
- Environmentally, there are no big changes compared to the baseline outcomes. The pressure from losses in the application of fertilizer is a bit lower and the pressure from unused manure surpluses a bit higher, due to the labor shifts from the crop to the livestock sector.
- The assumed growth of stable capacities possibly is on the conservative side in this scenario. Higher rates would lead to substitution of meat imports by feed imports, whereas farm incomes in the livestock sector would be higher, but obviously, manure disposal also.

The *high R&D scenario* shows that a considerable reduction in dependence on agricultural imports is possible, jointly with an alleviation of environmental pressures, provided that the additional R&D expenditures are successful in generating innovations that farmers can adopt. However, a substantial part of the gains will accrue to consumers rather than to farmers, because of drops in prices. Some details:

- Technical progress leads to significantly higher output of both crops and livestock products. Since non-agricultural incomes and urbanization rates remain unchanged, only a small part of the additional output is consumed domestically and, hence, foreign trade must absorb most of the differences.

- Higher export levels result for, especially, rice, fruits and vegetables and lower import levels for, especially, sugar, vegetable oil, pork and feed. In all, the agricultural trade deficit falls with more than 50%.
- Commodities not absorbed through additional exports see their prices diminish. This applies particularly to wheat and vegetables.
- Drops in prices limit the gains for crop farmers. Their value added per manyear goes up by 3.7% annually against 3.6% in the baseline scenario. Livestock farmers do not face such price decreases, and their value added per manyear goes up by 4.9% against 4.7% in the baseline.

Finally, the *enhanced irrigation scenario* shows outcomes similar to those of the high R&D scenario. Here also the agricultural trade balance improves and consumer welfare improves, while farmers themselves have to cope with the 'price trap', this time even with sharper geographic differences because of the location-specific nature of the added irrigation. Therefore, large groups of farmers who do not participate in the land improvement merely experience the disadvantages of falling prices. The scenario operates as follows:

- Output is reallocated towards crops that dominate the crop mix on irrigated land, especially towards rice, wheat and vegetables, and also to maize. For wheat and vegetables the output increases are lower than expected due to similar price declines as in the high R&D scenario, whereas maize (of which more than half grows on rainfed land in the baseline) benefits from the declines in these competing crops.
- Higher export levels result for rice and vegetables, and lower export levels for fruits, whereas food imports remain largely unchanged and feed imports become less. The agricultural trade deficit falls with about 15%.
- Only part of the benefits from the additional irrigation works accrues to crop farmers. Their value added is in 2030 about 0.5% higher than in the baseline scenario, but without price falls it would have been 1% higher. The remainder of the benefits ends up with the consumers.
- Effects on per capita incomes differ strongly across regions. Despite the nationwide rise in per capita incomes by 0.5%, crop farmers are worse off in many counties, especially those in the regions North, South and Plateau.
- The environmental pressures are higher, as fertilizer use is higher on irrigated land than on rainfed land.

Key questions in agricultural development

Against the background of these scenario results we now return to the key agricultural development issues raised in section 2, and discuss these in the same order.

1) *Import dependence*. China's feed grain imports remain manageable, in spite of the higher meat demand generated by continued income growth and urbanization. Import flows are largest in the high income scenario, with in 2030 maize imports of 26 million ton, carbohydrate feed imports of 19 million ton grain equivalent and protein feed imports close to 40 million ton cake/bran equivalent, amounting to, respectively, 16%, 18% and 35% of domestic use. Hence, China becomes a major feed importer on the world market, but it can afford this because of its massive export surplus outside agriculture. Meat imports themselves also gain in importance. Under the high income scenario, a total import of 15.5 million ton results, one sixth of domestic consumption. The eventual ratio of feed to meat imports will

strongly depend on how much stable capacities are permitted to grow, which is in part guided by environmental and health concerns. The scenarios suppose that initially high rates gradually slow down, especially after 2020.

2) *Grain surplus.* The shift to luxury food, combined with technical progress in agriculture, will result in limited surpluses of food grains, particularly rice with exports of around 3 to 5 million ton in 2030. Wheat remains in autarky under most scenarios. However, under additional technical progress or enhanced irrigation efforts, the rice export flows tend to become much larger, even up to 10 million ton or more. This would undoubtedly cause the world price to decline, inducing downward pressure on the domestic price and triggering substitution away from rice. The current scenarios abstract from such feedbacks and, consequently, tend to overestimate the rise in export volumes.

3) *Meat and feed supply by poor farmers.* The question whether the rising meat demand is an opportunity for poor farmers, particularly those in disadvantaged areas needs a more detailed answer.

   First, let us consider meat itself. Total demand in the coastal regions North, East and South increases between 2003 and 2030 with about 25 million ton of which foreign imports provide 9 million ton. Hence, a fair share is provided by domestic farmers. Who are these? Looking at the interregional trade flows, as indicators of 'long-distance' trade, we observe increases of meat surpluses exported from Northeast (from 0.8 to 1.1 million ton), Central (from 1.5 to 1.9 million ton), Plateau (from 0.1 to 0.3 million ton of meat) and Northwest (from 0.5 to 0.6 million ton meat), or 1.1 million ton in total. Southwest, with fast growing population concentrations, turns into a minor importer. Hence, most of the additional meat demand in North, East and South originates from within the own region. Although the model is not explicit about the pattern of trade flows inside the same region, the distribution of rise in meat supply over the counties, as reflected e.g. in the increase of livestock value added in Figure 5.3, strongly suggests that farmers in the hinterland of the coastal population concentrations benefit significantly.

   Second, the question comes up to what extent farmers in remote inland regions benefit indirectly, i.e. by supplying more feed to the coastal regions. For maize, there are substantial flows from Northeast and Northwest to the other regions but they remain more or less constant. For carbohydrate feed, there is a substantial flow from the Central region, but also this flow remains more or less constant. The third tradable feed commodity, protein feed, is imported by all regions, at increasing amounts. Hence, we may conclude that the increases in feed deficits in the regions North, East and South are mainly met by imports from abroad rather than by imports from remote inland regions.

   Hence we conclude that the main domestic suppliers of the increased amounts of meat to the industrialized coastal areas are the livestock farmers in the direct vicinity of these areas. More remote farmers benefit only to a limited extent via increased meat deliveries, and are not able to expand their current sales of feed.

   A final question is whether the livestock farmers who benefit are traditional farmers, specialized households, or industrial companies. In this respect, the simulation outcomes show that they are definitely not the traditional farmers, who see their output share declining significantly. Although the model itself does not make a further distinction between specialized households and industrial companies, the trends in Figure 2.5, that underlie the scenario specification, safely indicate that specialized households play a large role in supplying the additional meat.

4) *Northeast.* Northeastern China's role as feed supplier was already covered extensively. The region is a large maize seller at present and maintains this role in the baseline scenario but it

does not succeed in extending its surplus, not even under high R&D spending or enhanced irrigation efforts. Although its maize farm gate prices are among the lowest, the differences with other regions are small whereas the trade and transportation costs to bring maize to the neighboring North region are relatively high, with 0.07 Yuan/kg, about 7% of the product price. Reducing these trade and transport costs would help the expansion of these sales, as would higher international feed prices, especially if the world price of rice went down in parallel, in response to China's increased exports to the world market. Unless this happens, the region should focus on further reduction of production costs, for example by increased mechanization, as labor supply seems fairly limiting in this region.

5) *North*. In the baseline scenario the irrigated area in the whole North region declines with about 1.5 million hectare, and rainfed land with a similar amount. These reductions, jointly with the increased own feed demand, cause the region to lose its maize exports. Additional irrigation efforts would definitely help pushing up maize supply but a land conversion of 1.1 million hectare as in the enhanced irrigation scenario, from 15.5 to 16.6 million hectare in 2030, out of a total of 25.9 million hectare annual cropland, is by far insufficient to bring back maize exports. Instead, major efforts such as those of the South-to-North Water Transfer Project will be required to restore the maize-surplus in the North region, and even then only if maize prices remain sufficiently attractive to farmers compared to other crops.

6) *South*. On the basis of the simulations, the agricultural development in South, with as main crops rice, vegetables, fruits and sugar, and as main livestock products pork and poultry meat, does not appear particularly alarming compared to other regions, in terms of value added per manyear. Its 2003 levels are among the highest for crops as well as livestock, and so are the rates of increase. While over time the region loses in self-sufficiency, it can definitely afford this. As in other regions, the main concerns relate to the pressure on the environment, which is indeed very high in many Southern counties, and to the rising income gap compared to the non-agricultural sector.

7) *Trade liberalization*. As summarized already earlier in this section, enhanced trade liberalization causes price falls for imported commodities and price increases for exported commodities, compared to the baseline scenario. Farmer responses lead to higher supply of rice, fruits and vegetables, and lower supply of maize, sugar, vegetable oils and dairy. For wheat and eggs (in autarky) supply remains about the same, as well as for composite feeds (carbohydrate and protein feed) and also for meat (although meat prices fall somewhat). With respect to earnings from cropping, a mixed pattern of increases and decreases emerges, with a near balance on average. However, livestock farmers are worse off as their incomes are reduced, especially in coastal regions. In all, farm incomes go down on average. Clearly, consumers benefit through lower prices from the increased efficiency and see their welfare rise.

8) *Environment.* The simulations emphasize the pressure from fertilizer losses and unused manure. The pressure is already high at present, due to the high levels of fertilizer application and the large amounts of manure produced per hectare in several densely populated areas. Further intensification of agricultural production in both crop and livestock sectors, will only make it higher, on average at moderate rates but with the highest increases in the areas that are already vulnerable. Therefore, improving fertilizer use efficiency and opting for environmentally sustainable modes of manure disposal, treatment and recycling emerge as essential and key challenges.

Comparison with other models

In the beginning of the 1990s, when the country still had sizeable wheat imports whereas the rise in meat consumption had only just begun, the literature offered a wide range of projections about

China's future grain demand on the world market. Several studies were published with diverging forecasts for the year 2000, as summarized in Huang, Rozelle and Rosegrant (1999). At one extreme, China was predicted to have the capacity of becoming a large net exporter of grain, possibly even up to 50 million ton. At the other extreme, there were analysts who believed that China would be a major grain importer in 2000, with amounts that even came close to 100 million ton. The country in fact turned out to become a net exporter of grain in 2000, with about 10 million ton, albeit largely due to the disposal of stocks built up in earlier years. By 2005, the situation was essentially still the same, with a net export of 4 million ton (NSBCa, various issues). Since the beginning of the new century, the publication of alternative forecasts has calmed down somewhat. The study of Huang, Rozelle and Rosegrant itself predicts net grain imports to increase to about 30 million ton by the year 2020, consisting mainly of feed grain, whereas simulations with IFPRI's IMPACT model point to imports of close to 50 million ton for the same year (Rosegrant et al., 2001). Compared to these estimates, our baseline projection has moderate imports of about 20 million ton maize in 2020 and 22 million ton in 2030.

Also with respect to the effects of trade liberalization, a comparison with the literature is possible. As mentioned earlier, we are less optimistic than most other studies about, especially, the effects on the livestock sector in the coastal areas. Yet, our results are less pessimistic on farm incomes than those of Diao, Fan and Zhang (2003). The differences with the other studies are mainly due to differences in resulting trade regime and assumed baseline tariff levels and to the impact of labor outflow on agricultural output.

Policy implications

The findings presented suggest challenges to farmers and traders as well as to government that in the new liberalized context has, apart from the task to provide the necessary infrastructural improvements, also the duty to ensure a proper functioning of markets, supported by adequate legal and financial systems, and to watch carefully over the social balance in the country. Furthermore, where markets do not or only partly exist, such as is the case for ecosystem services and environmental goods, government has a crucial role to play in combating negative externalities.

The concerns that emanate from the simulations with respect to farm incomes, regional development and environmental dangers are not new to government. They confirm the worries featuring prominently in recent strategic documents, such as the 2003 report on improvement of the socialist market system quoted in the introductory section (CPC, 2003) and the Eleventh Five-Year Plan launched in March 2006 (NDRCb, 2006). In particular, the second chapter of the latter on 'Building a new socialist countryside' (essentially coinciding with the New Rural Development Program issued just one month earlier) emphasizes the need for a broad package of measures that will reduce the income gap between farmers and non-farmers.

However, 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 choices in the further elaboration of these strategic policy directions. Simulations like those presented in the current report may contribute to this process by providing quantitative background on the problems and the effects of alternative measures. In this respect, the following policy implications would seem to emerge:

- In the coming decades, importing 5% or even 10% of grain (dominantly feed) is feasible and should not be considered as a threat to national grain security. The main directions for China to follow to protect its future grain security are to continue investing in agricultural technology, to maintain at least the current share of irrigated land and to improve the efficiency of agriculture in general and of its water use in particular.

- Simultaneously with import needs, there is a large export potential, may be up to 40-50 million ton of fruits and vegetables. If such a two-way traffic can be facilitated by corresponding investments in transportation and logistics, this would help making better use of China's comparative advantages in advancing labor-intensive and high value-added production of fruits and vegetables, avoiding China's comparative disadvantage in land-intensive production of maize and other feeds.
- With respect to national grain security policies, a shift in emphasis from all grain to food grain suggests itself. Government could redefine its grain security goals in terms of rice and wheat, the two major food grains, and accept a moderate level of feed imports. This would provide considerable protection against external political-economic threats, while being attainable without major distortions.
- In view of China's strong position on an increasing number of international non-agricultural markets, household food security will gradually become more of a concern than national food security. While China's aggregate supply of food grains is not expected to encounter serious problems, there will be millions of farm workers in rural areas, especially crop farmers in inland regions, who will without additional measures have an income of less than 1250 USD (of 1997) even in 2030, which is less than one quarter of the country's per capita GDP. Therefore, household food security is part of the policy agenda, in particular for farm workers with limited land holdings of their own.
- However, to improve farm incomes and reduce the gap with non-agriculture, supply side measures such as improvement of technology, increase of efficiency and extension of irrigated land are not sufficient, as part of the benefits will leak away to consumers. Such measures must be embedded in broader programs that will allow poor farmers to increase their incomes by participating in non-agricultural activities, thereby reducing labor surpluses in agriculture.
- 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.
- 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. This applies especially to the Northern region, where current groundwater levels seem extremely worrying. Furthermore, the enormous costs of the large diversion schemes of the South-to-North Water Transfer Project call for considerate use of the new water supplies and careful, albeit not full cost, water pricing of their use.
- The quantitative assessment of current and future nutrient loads associated with crop and livestock production shows various hot-spots of agro-environmental pressures, especially in densely populated areas, where irreversible ecological damage is looming and human health is at risk. To mitigate these pressures, fertilizer use efficiency will have to be improved and environmentally adequate ways of manure disposal, treatment and recycling to be found. For this, a mix of technological improvements, legislative measures and monitoring systems will be required, as well as economic incentives in the form of charges for negative externalities to enforce improved management practices and to relocate livestock activities to areas where the environmental dangers are best manageable.

- Geography plays a major role as determinant of both the difference in prospects between farmers and environmental impacts. This needs to be reflected in policy analysis and formulation that should, therefore, be geographically explicit and differentiated. This applies throughout but in particular to the interconnection between, on one hand, improved varieties and farming practices and, on the other hand, investments in land development and irrigation. At the same time, policy makers cannot be warned enough that technological measures that improve supply capacity will not help the farmers and often hurt them, if they lead to congestion in the transport infrastructure or other elements of the marketing chain. Even improved transportation infrastructure can hurt farmers. It is important for policy makers to anticipate such occurrences, and react with sufficient preparation. This is where spatially explicit modeling studies can contribute.

Future research
The Chinagro-model has produced a comprehensive quantitative assessment of future developments of China's agricultural economy, under alternative scenarios about exogenous driving forces. So far, the scenarios formulated are oriented more towards a subject area than to a specific policy. In the future, we intend to turn the model into a tool for the assessment of more specific and elaborate policy packages. To make this possible, the model and the scenario assumptions, also those not directly related to domestic policies, will have to be updated regularly in order to maintain the relevance of the outcomes. Also, changes in model specification will be needed, to address some of the shortcomings discovered so far. We mention some.

First, it will be necessary to allow for some form of endogenous representation of international prices faced by China. Second, the developments outside agriculture should not be treated fully exogenously, particularly in rural areas, where farmers and their relatives are directly involved in agricultural processing and other forms of off-farm employment that can critically contribute to farm income. This will make it possible to trace better the social implications of various trends and interventions. Third, the trade and transportation margins between domestic markets and between farmgate and local market are kept fixed under the scenarios studied. This keeps prices relatively rigid, though not fixed because of the endogenous routing of flows between regions. In practice the price transmission is known to depend on the flexibility of the segments along the chain. A processor who is relatively inflexible in determining his output level, as is often the case in dairy and sugar processing, will be more inclined to buffer price shocks, particularly when farmers are flexible in their choice of alternative crops, or can work off-farm at good wages. Consequently, a good assessment of this relative flexibility is critical both to obtain a realistic description of the impacts of price changes, and to develop adequate policy interventions that may strengthen the negotiation power of the socially weaker segments in the food chain. Finally, the various techniques to make more efficient and more sustainable use of scarce water and nutrients and to address health risks will have to appear more explicitly. Such are the topics on the agenda of the CATSEI-project, Chinagro's successor.

Appendix A. Crop and livestock activities and their correspondence to commodities

This appendix describes *crop and livestock activities* and how these map to commodities as traded on markets. In the Chinagro model this structure is represented by a matrix of fixed coefficients, denoted by *B* that maps from activities to commodities. Many of its coefficients vary across provinces and may be adjusted under a model scenario. To clarify the role of the *B*-matrix in the model, we repeat the steps (see Keyzer and Van Veen, 2005) according to which cropping and livestock outputs are being generated:

- for each land use type the aggregate yield per hectare or per animal place depends on the input of equipped labor and fertilizer or feed, as shown in Figure 3 of the main text,
- the aggregate output of a land use type is distributed over activities (crops respectively animals) via a Constant Elasticity of Substitution function,
- the activity levels are transformed into tradable model commodities via the mapping matrix *B*.

For crop activities the *B*-matrix is built up from three submatrices: one for direct food use, one for direct feed use and one for crop processing into main product and byproducts. These submatrices are aggregated using the shares of the three destinations as weights, taking into account also the shares of output reserved for seed and lost on the farm. For livestock activities such submatrices are not relevant and the commodity mapping can be stated directly.

Chinagro distinguishes 14 crops. Their definitions follow the yearbooks of the China Statistical Bureau. It expresses roots and tubers in grain equivalent by taking 20% of the actual weight. 'Other nonfood crops' are mainly tobacco and hemp. Chinagro includes melons in vegetables and not in fruits. All crops are measured in kg, with two qualifications: (i) roots and tubers are expressed in kg grain equivalent, and (ii) cotton is expressed in kg of fiber. Table A.1 shows the destinations of the crops, as assumed for the base year. The shares are the same across provinces and land use types.

Table A.1 Destination of crops, 1997 (in percentages)

Crop	Direct food	Direct feed	Processing	Seed	On-farm waste
Paddy	-	10	85	3	2
Wheat	-	8	87	3	2
Maize	15	80	-	3	2
Other grains	-	55	40	3	2
Root crops	35	50	10	2	3
Soybean	20	-	75	3	2
Groundnuts	30	-	65	3	2
Oilseeds	-	10	85	3	2
Sugarcane	-	12	85	1	2
Sugar beets	-	12	85	1	2
Fruit	95	-	-	-	5
Vegetables	70	20	5	-	5
Cotton	-	-	95	3	2
Other nonfood	-	-	95	3	2

As mentioned above, crop output is mapped to the Chinagro commodities separately for direct food, direct feed and processing. The mappings are shown in Tables A.2 – A.4, respectively. Before mentioning the three tables, the list of tradable Chinagro commodities and their unit of measurement is given.

1. Rice	(kg milled)	10. Pork	(kg carcass weight)
2. Wheat	(kg flour)	11. Poultry meat	(kg carcass weight)
3. Maize	(kg grain)	12. Milk	(kg)
4. Other staple food	(kg soybean equivalent)	13. Eggs	(kg)
5. Vegetable oil	(kg)	14. Fish	(kg)
6. Sugar	(kg refined)	15. Nonfood excl feed	(ten constant 1997 Yuan)
7. Fruits	(kg)	16. Carbohydrate feed	(megacal)
8. Vegetables	(kg)	17. Protein feed	(megacal)
9. Ruminant meat	(kg carcass weight)		

.

Table A.2 Crop-to-commodity mapping: direct food use

Crop	Commodity	Coefficient*
Maize	Maize	1.00
Root crops	Other staple food	0.83
Soybean	Other staple food	1.00
Groundnuts	Other staple food	1.17
Fruit	Fruit	1.00
Vegetables	Vegetables	1.00

* expressed in commodity units per crop unit

Table A.3 Crop-to-commodity mapping: direct feed use

Crop	Commodity	Coefficient*
Paddy	Carbohydrate feed	3.60
Wheat	Carbohydrate feed	3.34
Maize	Maize	1.00
Other grains	Carbohydrate feed	3.40
Root crops	Carbohydrate feed	4.50
Oilseeds	Protein feed	4.50
Sugarcane	Carbohydrate feed	0.30
Sugar beets	Carbohydrate feed	0.70
Vegetables	Carbohydrate feed	0.25

* expressed in commodity units per crop unit

Table A.4 Crop-to-commodity mapping: processing

Crop	Commodity	Coefficient*	Explanation
Paddy	Rice	0.73	Extraction rate milled rice
	Protein feed	0.36	Extraction rate bran 0.12, with 3.02 mcal/kg
Wheat	Wheat	0.75	Extraction rate wheat flour
	Protein feed	0.48	Extraction rate bran 0.18, with 2.65 mcal/kg
Other grains	Other staple food	0.20 – 0.40	Extraction rate flour 0.80, with price-based conversion
	Protein feed	0.27	Extraction rate bran 0.10, with 2.70 mcal/kg
Root crops	Other staple food	0.62	Extraction rate flour 0.75, with price-based conversion
	Carbohydrate feed	0.30	Extraction rate 0.20, with 1.50 mcal/kg
Soybean	Vegetable oil	0.15	Extraction rate oil
	Protein feed	2.59	Extraction rate cake 0.82, with 3.16 mcal/kg
Groundnuts	Vegetable oil	0.30	Extraction rate oil
	Protein feed	1.33	Extraction rate cake 0.385, with 3.46 mcal/kg
Oilseeds	Vegetable oil	0.35	Extraction rate oil
	Protein feed	1.86	Extraction rate cake 0.55, with 3.39 mcal/kg
Sugarcane	Sugar, refined	0.09	Extraction rate refined sugar
	Carbohydrate feed	0.05	Residual rate 0.025, with 1.94 mcal/kg
Sugar beets	Sugar, refined	0.10	Extraction rate refined sugar
	Carbohydrate feed	0.14	Residual rate 0.334, with 0.42 mcal/kg
Vegetables	Vegetables	0.85	Extraction rate processed vegetables
	Carbohydrate feed	0.08	Residual rate 0.14, with 0.60 mcal/kg
Cotton	Vegetable oil	0.27	Oil rate relative to fiber
	Nonfood	0.80 - 1.20	Price-based conversion of cotton fiber
	Protein feed	2.72	Cake rate relative to fiber 1.07, with 2.54 mcal/kg
Other nonfood	Nonfood	0.10 - 0.80	Price-based conversion of tobacco or hemp

* expressed in commodity units per crop unit (in case of provincial variation, the range is indicated)

Tables A.1 – A.4 show that most crop coefficients are established at national level, hence without provincial differences. Only in case of price-based conversion factors, provincially different coefficients may result. In these cases, the tables report the range of the provincial coefficients.

For livestock activities, the output structure is summarized in Table A.5. Most coefficients differ by livestock system and by province. In fact, the table rather than showing the coefficients themselves, for ease of presentation lists the base year information from which the coefficients were derived. The actual coefficients are expressed relative to the 1997 meat output (following the choice of the output unit of the activities in the model), which means that they can be obtained by dividing each element in the table by the corresponding meat output per animal place. Logically, then all meat coefficients in the initial *B*-matrix become one, but they can be increased over time in order to represent productivity increases.

Table A.5 Commodity output of livestock activities (ranges of regional averages)

Livestock system	Activity	1997 output in commodity units per animal place of the activity*			
		Meat	Milk	Eggs	Nonfood
Draught animals	Buffaloes	8	90	-	17 – 50
	Draught cattle	6 – 9	-	-	8 – 31
	Other	8 – 9	-	-	7 – 23
Grazing	Milk cattle	16 – 27	1176 – 1869	-	11 – 22
	Meat cattle	27 – 75	-	-	1 - 3
	Sheep and goat	2 – 5	7 – 9	-	1 – 2
	Yaks	7	20	-	2 – 3
Traditionally mixed ruminants	Milk cattle	17 – 25	1624 - 2623	-	34 – 62
	Meat cattle	32 – 91	-	-	4 – 9
	Sheep and goat	4 – 7	7 – 9	-	1 – 2
Specialized dairy	Milk cattle	17 – 25	2286 - 4237	-	4 - 9
Traditionally mixed non-ruminants	Pigs	53 – 96	-	-	-
	Poultry	2 – 3	-	1 – 8	-
Intensified non-ruminants	Pigs	81 – 130	-	-	-
	Poultry	3 – 5	-	4 – 13	-

* In fact, the model knows the concept of ‘animal place’ only for livestock systems and not for activities; here, it is merely used to facilitate the interpretation of the figures; actual model coefficients are expressed relative to the 1997 meat output, hence obtained by dividing each figure by the corresponding meat output.

The intervals in Table A.5 indicate the range of the regional differences of the yields per animal place. The table shows that these differences may be quite large. They are actually even larger since the model uses provincial information. Different species of animals, different production habits within mixed systems and different degrees of intensification cause this variation across provinces. For example, the number of chicken layers versus broilers may be rather diverse across provinces, and creates the wide ranges for poultry meat and eggs.

In addition to the output mentioned in Tables A.1 – A.5, crop and livestock activities produce local outputs that are hardly tradable: crop residuals, manure and draught power. These outputs are directly used on-farm within the same county. Only to the extent that they are considered tradable, they are added to the *B*-matrix, as carbohydrate feed or nonfood. The model assumes that 5% of crop residuals and 10% of manure is tradable. Compared to the tables above, the resulting coefficients are rather small. They are not presented separately.

Finally, the coefficients are reported that are used to calculate manure nutrient discharges from the feed intake of animals. Table A.6 shows the nutrient content by type of feed. Local feed is being distinguished by animal system, with the content following the system-specific composition in terms of crop residuals, grass, green fodder and household waste. Table A.7 shows the discharge rates assumed for each livestock system. The smaller the share of growing animals, the closer to one the discharge rates will be. These rates have been established by calibration to the nutrient discharge rates of Ermolieva et al. (2005). As last step in the calculations, the amounts of P and K are converted into the oxides P_2O_5 and K_2O, following the standard way of measurement in fertilizer application. The conversion factors are 2.290 respectively 1.205, determined on the basis of physical weights.

Table A.6 Nutrient contents of feed, in kg N, P or K per Gcal

	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Tradable feed			
Maize	4.30	0.70	0.85
Carbohydrate feed	4.00	0.70	2.00
Protein feed	16.00	2.75	6.00
Local feed of			
Draught animals	6.50	1.75	3.50
Grazing animals	7.50	1.25	8.00
Traditional ruminants	6.50	1.75	3.50
Specialized dairy	6.00	1.50	2.00
Traditional pork and poultry	5.00	0.75	2.50
Intensified pork and poultry	5.00	0.75	2.50

Table A.7 Nutrient discharge rates by livestock system

Draught animals	98%
Grazing animals	95%
Traditional ruminants	90%
Specialized dairy	85%
Traditional pork and poultry	80%
Intensified pork and poultry	65%

Appendix B. Tables with outcomes of the different scenarios

Contents:

Table B.1 Supply, demand, net outflow and self-sufficiency rate of major crop food items under different scenarios (million tons)

	Baseline			Liberalization			High growth			High R&D			Irrigation up		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
Supply															
Rice (milled)	129.8	136.5	136.0	129.9	138.1	137.5	130.3	137.8	137.2	131.4	144.2	147.5	131.1	145.4	151.4
Wheat flour	83.5	85.2	84.1	83.6	85.5	84.4	83.9	84.8	83.0	84.6	86.8	87.8	84.0	86.2	85.9
Vegetable oil	9.8	10.1	10.2	9.7	9.9	10.0	9.9	10.2	10.3	10.2	10.8	11.2	9.9	10.2	10.4
Sugar	9.0	9.5	9.5	8.8	8.8	8.8	9.0	9.5	9.5	9.3	10.0	10.2	8.9	9.3	9.2
Fruit	69.2	74.7	78.3	69.6	75.5	79.1	69.4	74.4	77.3	70.0	75.9	80.1	68.9	73.7	76.7
Vegetables	253.7	268.3	278.7	255.4	272.7	284.2	257.0	269.9	279.5	258.1	276.9	287.3	255.7	271.8	282.0
Demand															
Rice (milled)	129.8	132.1	131.7	129.9	131.8	131.4	130.3	130.7	129.2	131.4	132.2	131.9	131.1	132.2	131.9
Wheat flour	83.4	85.2	84.1	83.5	85.5	84.4	83.8	84.8	83.0	84.5	86.8	85.8	83.9	86.2	85.8
Vegetable oil	16.6	18.3	19.4	16.7	18.8	19.8	16.7	18.7	20.3	16.6	18.3	19.4	16.6	18.3	19.4
Sugar	10.7	11.7	12.6	10.8	12.5	13.4	11.0	12.3	13.3	10.7	11.7	12.6	10.7	11.7	12.6
Fruit	65.2	70.8	73.6	64.7	70.0	72.9	66.6	73.6	76.6	65.3	70.9	73.7	65.1	70.8	73.6
Vegetables	246.1	260.5	265.4	245.9	259.9	264.3	248.6	263.7	267.4	249.2	264.2	271.9	246.7	260.9	267.4
Net outflow															
Rice (milled)	0.0	4.4	4.3	0.0	6.3	6.1	0.0	7.1	8.0	0.0	12.0	15.6	0.0	13.3	19.5
Wheat flour	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.1	0.0	2.0	0.1	0.0	0.1
Vegetable oil	-6.8	-8.2	-9.1	-7.0	-8.9	-9.7	-6.8	-8.5	-10.1	-6.3	-7.5	-8.2	-6.7	-8.1	-9.0
Sugar	-1.7	-2.2	-3.1	-2.0	-3.8	-4.7	-1.9	-2.8	-3.9	-1.4	-1.7	-2.4	-1.7	-2.3	-3.3
Fruit	4.0	3.8	4.7	5.0	5.5	6.2	2.8	0.8	0.7	4.8	5.0	6.4	3.8	2.9	3.1
Vegetables	7.6	7.8	13.3	9.6	12.8	20.0	8.4	6.2	12.1	9.0	12.7	15.4	9.0	10.9	14.6

Table B.1 continued

	Baseline			Liberalization			High growth			High R&D			Irrigation up		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
Self-sufficiency (%)															
Rice (milled)	100	103	103	100	105	105	100	105	106	100	109	112	100	110	115
Wheat flour	100	100	100	100	100	100	100	100	100	100	100	102	100	100	100
Vegetable oil	59	55	53	58	53	51	59	55	51	62	59	58	60	56	54
Sugar	84	81	75	81	70	65	82	77	71	87	86	81	83	79	73
Fruit	106	105	106	108	108	109	104	101	101	107	107	109	106	104	104
Vegetables	103	103	105	104	105	108	103	102	105	104	105	106	104	104	105

Table B.2 Supply, demand, net outflow and self-sufficiency rate of livestock products under different scenarios (million tons)

	Baseline			Liberalization			High growth			High R&D			Irrigation up		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
Supply															
Beef and mutton	6.0	7.4	8.5	6.0	7.4	8.5	6.0	7.4	8.5	6.0	7.4	8.5	6.0	7.4	8.5
Pork	40.9	49.0	53.3	41.1	48.8	53.1	41.8	50.7	55.3	41.6	50.3	56.2	41.0	49.0	53.4
Poultry meat	10.2	12.6	14.6	10.1	12.6	14.5	10.4	12.9	15.1	10.4	13.2	15.3	10.2	12.7	14.6
Milk	18.8	24.5	28.7	18.6	23.6	27.9	18.9	24.7	29.4	19.0	25.1	29.8	18.8	24.5	28.7
Egg	20.3	25.4	29.2	20.1	25.5	29.1	20.5	26.0	30.1	20.6	26.4	30.5	20.3	25.4	29.2
Demand															
Beef and mutton	6.0	7.4	8.5	6.0	7.4	8.7	6.0	7.4	9.3	6.0	7.4	8.5	6.0	7.4	8.5
Pork	40.9	49.0	59.5	41.1	50.1	61.9	41.8	50.7	64.9	41.6	50.3	60.1	41.0	49.0	59.5
Poultry meat	10.2	13.2	17.5	10.5	13.7	18.5	10.8	14.2	20.2	10.4	13.5	17.5	10.2	13.2	17.5
Milk	22.7	36.6	57.6	23.2	39.6	61.7	24.1	42.2	69.2	22.7	36.6	57.6	22.7	36.6	57.6
Egg	20.3	24.6	29.2	20.1	24.5	29.1	20.5	26.0	30.1	20.6	24.7	30.5	20.3	24.6	29.2
Net outflow															
Beef and mutton	0.0	0.0	0.0	0.0	0.0	-0.2	0.0	0.0	-0.7	0.0	0.0	0.0	0.0	0.0	0.0
Pork	0.0	0.0	-6.2	0.0	-1.3	-8.8	0.0	0.0	-9.7	0.0	0.0	-4.0	0.0	0.0	-6.2
Poultry meat	0.0	-0.6	-2.9	-0.3	-1.1	-4.0	-0.4	-1.2	-5.1	0.0	-0.3	-2.2	0.0	-0.6	-2.9
Milk	-3.9	-12.1	-28.9	-4.6	-15.9	-33.7	-5.2	-17.5	-39.8	-3.6	-11.5	-27.8	-3.9	-12.1	-28.9
Egg	0.0	0.8	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.7	0.0	0.0	0.8	0.0
Self-sufficiency (%)															
Beef and mutton	100	100	100	100	100	98	100	100	92	100	100	100	100	100	100
Pork	100	100	90	100	97	86	100	100	85	100	100	93	100	100	90
Poultry meat	100	96	84	97	92	78	96	91	75	100	98	87	100	96	83
Milk	83	67	50	80	60	45	78	59	43	84	69	52	83	67	50
Egg	100	103	100	100	104	100	100	100	100	100	107	100	100	103	100

Table B.3 Supply, demand, net outflow and self-sufficiency rate of tradable feeds under different scenarios

	Baseline			Liberalization			High growth			High R&D			Irrigation up		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
Supply															
Maize	113.1	118.9	118.8	111.4	114.8	114.9	114.4	119.1	119.0	118.1	126.7	129.8	113.9	119.6	120.5
Carbohydrate feed	297.8	289.8	275.8	297.3	289.2	275.3	299.2	289.3	274.6	304.8	303.6	295.6	297.7	291.2	278.8
Protein feed	203.6	212.3	213.4	203.4	211.8	213.0	205.3	213.1	213.7	209.0	222.7	229.5	205.3	217.7	222.9
Demand															
Maize, food	18.4	18.3	17.8	18.6	18.8	18.2	18.3	17.9	17.1	18.4	18.4	17.9	18.4	18.4	17.8
Maize, feed	108.0	120.6	123.0	108.0	120.2	122.4	109.0	122.4	124.3	107.7	120.2	123.1	108.1	120.5	122.9
Carbohydrate feed	336.6	348.3	332.4	336.6	347.3	331.2	339.0	353.3	336.7	335.7	347.2	332.6	336.6	348.1	332.3
Protein feed	284.4	320.1	327.0	284.3	319.0	325.3	286.7	324.7	330.3	283.4	319.0	327.2	284.5	319.9	326.9
Net outflow															
Maize	-13.3	-20.0	-22.0	-15.2	-24.2	-25.7	-12.9	-21.2	-22.4	-8.0	-11.9	-11.1	-12.6	-19.3	-20.2
Carbohydrate feed	-38.8	-58.5	-56.6	-39.3	-58.1	-55.9	-39.8	-64.0	-62.1	-30.9	-43.6	-37.0	-38.9	-56.9	-53.5
Protein feed	-80.8	-107.8	-113.6	-80.9	-107.2	-112.3	-81.4	-111.6	-116.6	-74.4	-96.3	-97.7	-79.1	-102.2	-104.0
Self-sufficiency (%)															
Maize	89	86	84	88	83	82	90	85	84	94	91	92	90	86	86
Carbohydrate feed	88	83	83	88	83	83	88	82	82	91	87	89	88	84	84
Protein feed	72	66	65	72	66	65	72	66	65	74	70	70	72	68	68

Note: the unit for maize is million tons, and the unit for carbohydrate feed and protein feed is million Gcal.

Table B.4 Per capita consumption of grain and meat under different scenarios (kg/person/year)

	Grain					Meat and egg				
	1997	2003	2010	2020	2030	1997	2003	2010	2020	2030
Baseline										
Rural	194.0	196.8	193.3	192.0	192.4	26.7	31.3	34.8	38.4	44.0
Urban	130.8	129.6	128.3	127.8	127.3	67.5	74.1	81.5	90.3	101.4
National	172.5	170.8	164.8	159.8	155.0	40.5	47.9	55.3	64.4	77.0
Liberalization										
Rural	194.0	196.8	193.7	192.3	192.7	26.7	31.3	34.9	39.3	45.9
Urban	130.8	129.6	128.5	128.0	127.5	67.5	74.1	81.7	91.4	104.2
National	172.5	170.8	165.1	160.1	155.2	40.5	47.9	55.5	65.4	79.5
High growth										
Rural	194.0	196.8	195.3	193.3	193.4	26.7	31.3	35.2	38.5	45.7
Urban	130.8	129.6	129.5	128.7	128.0	67.5	74.1	82.4	90.9	105.0
National	172.5	170.8	165.5	158.0	151.6	40.5	47.9	56.6	67.1	83.6
High R&D										
Rural	194.0	196.8	195.9	193.6	194.3	26.7	31.3	35.5	39.5	45.0
Urban	130.8	129.6	129.6	128.6	128.1	67.5	74.1	82.5	91.7	103.0
National	172.5	170.8	166.8	161.0	156.2	40.5	47.9	56.1	65.6	78.3
Irrigation up										
Rural	194.0	196.8	195.0	193.0	194.3	26.7	31.3	34.8	38.4	44.0
Urban	130.8	129.6	129.1	128.3	128.1	67.5	74.1	81.5	90.3	101.5
National	172.5	170.8	166.1	160.6	156.2	40.5	47.9	55.3	64.4	77.1

Table B.5 Market prices of main crop products in selected regions under different scenarios (Yuan/kg)

	Baseline			Liberalization			High growth			High R&D			Irrigation up		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
North															
Rice (milled)	2.06	2.12	1.96	2.06	2.14	1.99	2.03	2.11	1.96	1.94	2.11	1.96	1.96	2.11	1.96
Wheat flour	1.38	1.33	1.23	1.37	1.31	1.21	1.35	1.29	1.16	1.28	1.20	1.10	1.33	1.25	1.10
Maize	1.05	1.09	1.04	1.01	0.99	0.96	1.05	1.09	1.04	1.05	1.08	1.03	1.05	1.08	1.04
Vegetable oil	5.44	5.23	4.89	5.28	4.67	4.42	5.44	5.23	4.89	5.44	5.23	4.89	5.44	5.23	4.89
Sugar	2.71	2.73	2.54	2.60	2.26	2.13	2.71	2.73	2.54	2.71	2.73	2.54	2.71	2.73	2.54
Fruit	1.51	1.52	1.54	1.56	1.59	1.61	1.51	1.52	1.54	1.51	1.52	1.54	1.51	1.52	1.54
Vegetables	0.94	0.99	1.04	0.94	1.00	1.05	0.94	0.99	1.04	0.88	0.92	0.90	0.93	0.98	0.97
Central															
Rice (milled)	1.50	1.55	1.40	1.49	1.58	1.42	1.46	1.55	1.39	1.37	1.54	1.39	1.40	1.54	1.39
Wheat flour	1.33	1.29	1.18	1.32	1.26	1.16	1.30	1.24	1.12	1.23	1.15	1.05	1.28	1.20	1.05
Maize	1.15	1.18	1.13	1.11	1.08	1.05	1.15	1.18	1.13	1.15	1.18	1.13	1.15	1.18	1.13
Vegetable oil	5.44	5.23	4.89	5.27	4.67	4.41	5.44	5.23	4.89	5.44	5.23	4.89	5.44	5.23	4.89
Sugar	2.72	2.74	2.55	2.61	2.27	2.14	2.72	2.74	2.55	2.72	2.74	2.55	2.72	2.74	2.55
Fruit	1.74	1.76	1.78	1.79	1.83	1.84	1.75	1.76	1.78	1.74	1.75	1.77	1.74	1.76	1.78
Vegetables	0.77	0.82	0.87	0.78	0.83	0.88	0.77	0.83	0.88	0.72	0.75	0.73	0.76	0.81	0.84
Southwest															
Rice (milled)	1.93	1.98	1.83	1.92	2.01	1.85	1.89	1.97	1.82	1.80	1.97	1.82	1.83	1.97	1.82
Wheat flour	1.40	1.36	1.25	1.39	1.33	1.23	1.37	1.31	1.19	1.30	1.22	1.12	1.35	1.27	1.12
Maize	1.12	1.15	1.10	1.08	1.06	1.02	1.12	1.15	1.10	1.12	1.15	1.10	1.12	1.15	1.10
Vegetable oil	5.43	5.23	4.89	5.27	4.67	4.41	5.44	5.23	4.89	5.44	5.23	4.89	5.44	5.23	4.89
Sugar	2.69	2.71	2.52	2.58	2.25	2.13	2.69	2.71	2.52	2.69	2.71	2.52	2.69	2.70	2.52
Fruit	1.77	1.79	1.81	1.82	1.86	1.87	1.78	1.79	1.81	1.77	1.78	1.80	1.77	1.79	1.81
Vegetables	1.05	1.10	1.10	1.06	1.11	1.15	1.05	1.11	1.09	1.00	1.03	1.01	1.04	1.09	1.09

Table B.6 Market prices of main livestock products in selected regions under different scenarios (Yuan/kg)

	Baseline			Liberalization			High growth			High R&D			Irrigation up		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
North															
Beef and mutton	15.39	17.45	21.44	15.36	17.40	20.47	17.19	22.34	23.94	15.38	17.42	21.40	15.39	17.45	21.44
Pork	14.78	19.02	21.81	14.69	18.18	20.63	15.35	21.01	23.59	14.26	17.97	21.51	14.76	19.01	21.78
Poultry meat	14.16	18.06	20.43	13.37	17.65	19.52	14.26	21.17	22.49	13.57	16.78	20.42	14.14	18.06	20.43
Milk	2.82	2.63	2.46	2.69	2.27	2.14	2.82	2.63	2.46	2.82	2.63	2.46	2.82	2.63	2.46
Egg	4.85	5.44	5.91	4.92	5.50	5.93	5.01	5.44	6.27	4.69	5.44	5.38	4.85	5.44	5.91
Central															
Beef and mutton	14.81	16.87	20.86	14.78	16.82	19.90	16.61	21.77	23.36	14.80	16.84	20.82	14.81	16.87	20.86
Pork	14.35	18.59	21.39	14.26	17.75	20.20	14.92	20.58	23.16	13.83	17.54	21.08	14.33	18.58	21.35
Poultry meat	16.26	20.16	22.52	15.47	19.75	20.50	16.36	23.26	23.22	15.67	18.88	22.51	16.24	20.16	22.52
Milk	2.60	2.43	2.27	2.47	2.07	1.96	2.60	2.43	2.27	2.60	2.43	2.27	2.60	2.43	2.27
Egg	6.72	7.31	7.78	6.79	7.36	7.80	6.88	7.31	8.14	6.56	7.28	7.25	6.72	7.31	7.78
Southwest															
Beef and mutton	14.36	16.41	20.41	14.33	16.37	19.44	16.16	21.31	22.91	14.34	16.39	20.36	14.36	16.41	20.41
Pork	13.52	17.76	21.15	13.43	16.93	20.80	14.09	19.75	22.79	13.00	16.71	20.26	13.50	17.75	21.13
Poultry meat	19.18	20.68	21.80	18.29	18.74	19.18	19.19	21.60	21.81	18.59	20.68	21.80	19.16	20.68	21.80
Milk	2.48	2.31	2.21	2.35	1.96	1.90	2.48	2.34	2.21	2.48	2.31	2.21	2.48	2.31	2.21
Egg	6.94	7.52	8.00	7.01	7.57	8.02	7.10	7.53	8.36	6.77	7.31	7.47	6.94	7.53	7.99

Table B.7 Allocation of on-farm labor to land use types under different scenarios (million full-time equivalent year)

	Baseline			Liberalization			High growth			High R&D			Irrigation up		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
Crop sector	**190.9**	**171.6**	**144.1**	**190.8**	**172.0**	**144.8**	**188.2**	**163.8**	**134.4**	**191.1**	**172.0**	**144.0**	**191.0**	**172.1**	**144.8**
Irrigated land	101.5	89.5	73.6	101.6	90.0	74.2	100.0	85.7	68.9	101.0	89.6	73.6	102.9	93.7	79.4
Rain-fed land	79.7	72.4	61.2	79.6	72.3	61.2	78.5	68.5	56.3	80.4	72.7	61.1	78.4	68.8	56.1
Tree cropping land	9.7	9.7	9.3	9.7	9.7	9.3	9.7	9.6	9.2	9.7	9.7	9.3	9.7	9.7	9.3
Livestock sector	**44.3**	**47.1**	**45.0**	**44.3**	**46.7**	**44.3**	**44.9**	**48.2**	**45.3**	**44.0**	**46.6**	**45.1**	**44.3**	**47.1**	**45.1**
Draught animal	4.2	3.3	2.4	4.2	3.3	2.4	4.2	3.3	2.4	4.2	3.3	2.4	4.2	3.3	2.4
Grazing system	1.4	1.4	1.3	1.4	1.4	1.3	1.4	1.3	1.3	1.4	1.4	1.3	1.4	1.4	1.3
Trad. mixed ruminant	5.3	6.3	6.6	5.3	6.3	6.6	5.3	6.3	6.6	5.3	6.3	6.6	5.3	6.3	6.6
Intens. dairy	0.6	0.7	0.8	0.6	0.6	0.7	0.6	0.7	0.8	0.6	0.7	0.8	0.6	0.7	0.8
Trad. mixed nonruminant	25.8	25.4	22.1	25.9	25.2	21.8	26.2	26.1	22.3	25.6	25.1	22.1	25.9	25.4	22.2
Intens. nonruminant	7.0	10.0	11.8	7.0	9.9	11.5	7.2	10.4	11.9	6.9	9.9	11.8	7.0	10.1	11.8
Total on-farm labor	**235.1**	**218.7**	**189.1**	**235.1**	**218.7**	**189.1**	**233.1**	**212.0**	**179.7**	**235.1**	**218.7**	**189.1**	**235.4**	**219.3**	**189.9**

Table B.8 Farming value added and its share in total GDP, under different scenarios (billion Yuan)

	Baseline			**Liberalization**			**High growth**			**High R&D**			**Irrigation up**		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
Cropping sector	**1250.3**	**1481.1**	**1525.6**	**1243.9**	**1467.9**	**1523.1**	**1253.2**	**1452.8**	**1474.7**	**1246.4**	**1515.8**	**1564.8**	**1239.0**	**1492.6**	**1538.3**
Irrigated cropping	699.7	819.2	827.4	696.0	818.3	830.1	700.4	810.9	809.4	685.4	838.6	851.1	693.8	858.1	890.8
Rainfed cropping	477.7	582.5	614.2	472.5	566.5	605.0	479.8	563.0	582.7	488.1	598.0	629.8	472.3	555.2	563.4
Tree cropping	73.0	79.4	84.1	75.4	83.2	88.0	73.0	79.0	82.7	73.0	79.2	83.9	72.9	79.4	84.1
Livestock sector	**568.4**	**987.0**	**1339.8**	**559.3**	**929.7**	**1223.8**	**621.9**	**1185.5**	**1492.5**	**551.6**	**965.9**	**1387.2**	**568.0**	**987.6**	**1340.4**
Draught animal	-24.2	-20.9	-14.0	-24.1	-20.7	-14.2	-23.2	-18.7	-13.2	-24.2	-20.9	-14.0	-24.2	-20.9	-14.0
Grazing ruminant	19.7	24.7	34.0	19.3	23.8	32.0	21.9	31.7	38.2	19.7	24.7	34.0	19.7	24.8	34.1
Trad. ruminant	32.4	54.0	91.9	31.9	52.5	85.0	39.8	80.1	106.8	32.3	53.9	91.7	32.4	54.0	91.9
Intens. dairy	14.0	17.9	20.9	12.5	12.2	15.7	14.4	19.3	23.8	14.5	19.1	23.0	14.0	17.9	21.0
Trad. nonruminant	323.1	481.3	549	320.5	457.4	509.9	347.5	560.7	602.5	313.4	467.6	567.5	323.0	481.8	549.8
Intens. nonruminant	203.5	430.0	658	199.1	404.7	595.6	221.5	512.3	734.5	195.9	421.6	685.0	203.2	430.1	657.8
Related sectors	**14.0**	**8.9**	**5.3**	**14.0**	**8.9**	**5.3**	**13.8**	**8.5**	**4.9**	**14.0**	**8.9**	**5.3**	**14.0**	**8.9**	**5.3**
Farming GDP	**1833**	**2477**	**2871**	**1817**	**2407**	**2752**	**1889**	**2647**	**2972**	**1812**	**2491**	**2957**	**1821**	**2489**	**2884**
Total GDP	21326	39680	64769	21311	39612	64653	21802	43438	78030	21305	39693	64854	21314	39692	64782
Farming share (%)	8.6	6.2	4.4	8.5	6.1	4.3	8.6	6.1	3.8	8.5	6.3	4.6	8.5	6.3	4.5

Note: related sectors cover collection of household waste, nightsoil and green feed

Table B.9 Farming value added by region under different scenarios (billion Yuan)

Regions	Baseline			Liberalization			High growth			High R&D			Irrigation up		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
Cropping sector															
North	264.5	296.6	299.5	263.0	292.3	297.4	264.7	290.2	289.5	263.8	299.8	300.7	263.5	297.9	298.5
Northeast	84.4	93.2	86.6	82.9	89.7	85.2	84.6	91.4	83.9	84.5	96.9	91.7	83.5	94.7	89.8
East	196.6	229.5	232.5	196.0	229.1	234.0	199.6	228.9	226.9	195.3	235.8	239.7	193.8	230.5	232.9
Central	177.0	204.1	212.6	176.5	204.4	213.6	176.4	201.8	209.8	174.9	210.7	219.6	174.1	207.0	215.8
South	221.5	277.7	282.4	221.2	276.9	283.1	223.8	272.2	269.8	221.3	284.0	289.1	219.1	277.4	280.3
Southwest	203.6	258.0	282.8	202.3	255.9	282.6	201.2	248.5	268.7	203.3	264.1	291.6	201.4	259.4	286.3
Plateau	3.4	3.9	4.0	3.4	3.8	4.0	3.4	3.8	3.9	3.4	3.9	4.0	3.4	3.8	3.9
Northwest	99.3	118.2	125.2	98.6	115.9	123.2	99.5	116.1	122.3	99.9	120.7	128.3	100.2	122.0	130.9
China	**1250.3**	**1481.1**	**1525.6**	**1243.9**	**1467.9**	**1523.1**	**1253.2**	**1452.8**	**1474.7**	**1246.4**	**1515.8**	**1564.8**	**1239.0**	**1492.6**	**1538.3**
Livestock sector															
North	117.1	205.4	283.5	115.4	197.5	266.0	130.1	253.3	329.6	113.2	201.3	292.9	116.9	205.7	283.5
Northeast	52.2	89.0	119.6	51.0	85.2	113.3	57.0	108.9	134.3	50.6	86.5	123.2	52.2	89.2	119.9
East	73.5	121.4	160.2	71.9	115.6	133.9	80.0	146.6	168.2	71.3	118.1	168.9	73.4	121.4	160.3
Central	85.9	147.7	193.8	85.1	140.1	180.1	93.4	176.0	220.5	83.5	143.2	202.8	86.0	147.9	194.0
South	102.6	184.2	240.9	100.3	166.6	201.1	109.7	208.4	251.1	100.3	183.2	255.7	102.5	184.3	241.2
Southwest	82.5	148.3	206.0	81.8	138.8	199.1	91.2	178.9	233.6	79.2	144.2	208.9	82.4	148.2	205.9
Plateau	5.7	9.1	14.2	5.6	8.5	12.9	6.4	11.8	15.9	5.7	9.1	14.3	5.7	9.1	14.2
Northwest	48.9	82.0	121.6	48.1	77.4	117.4	54.2	101.6	139.2	47.9	80.5	120.6	48.8	81.9	121.6
China	**568.4**	**987.0**	**1339.8**	**559.3**	**929.7**	**1223.8**	**621.9**	**1185.5**	**1492.5**	**551.6**	**965.9**	**1387.2**	**568.0**	**987.6**	**1340.4**

Table B.10 Farming value added per laborer and its annual growth rate, by region, under different scenarios

Regions	Baseline			Liberalization			High growth			High R&D			Irrigation up		
	2003 (Yuan)	2030 (Yuan)	Growth (%)	2003 (Yuan)	2030 (Yuan)	Growth (%)	2003 (Yuan)	2030 (Yuan)	Growth (%)	2003 (Yuan)	2030 (Yuan)	Growth (%)	2003 (Yuan)	2030 (Yuan)	Growth (%)
Cropping sector															
North	3571	8862	3.42	3571	8771	3.38	3571	9197	3.57	3571	8919	3.45	3571	8737	3.37
Northeast	5880	14389	3.37	5880	14103	3.29	5880	15207	3.58	5880	15224	3.59	5880	14718	3.46
East	4436	11275	3.52	4436	11258	3.51	4436	11797	3.69	4436	11638	3.64	4436	11278	3.52
Central	4532	11368	3.46	4532	11369	3.47	4532	12014	3.68	4532	11769	3.60	4532	11579	3.54
South	5375	13303	3.41	5375	13223	3.39	5375	13728	3.53	5375	13648	3.51	5375	13253	3.40
Southwest	3351	9558	3.96	3351	9540	3.95	3351	9708	4.02	3351	9845	4.07	3351	9654	4.00
Plateau	2490	5479	2.96	2490	5411	2.92	2490	5696	3.11	2490	5479	2.96	2490	5301	2.84
Northwest	3527	9289	3.65	3527	9139	3.59	3527	9634	3.79	3527	9507	3.74	3527	9546	3.76
China	**4127**	**10584**	**3.55**	**4127**	**10521**	**3.53**	**4127**	**10973**	**3.69**	**4127**	**10864**	**3.65**	**4127**	**10623**	**3.56**
Livestock sector															
North	7450	24784	4.55	7450	23518	4.35	7450	28409	5.08	7450	25465	4.66	7450	24736	4.54
Northeast	12964	45824	4.79	12964	43737	4.61	12964	51665	5.25	12964	47388	4.92	12964	45586	4.77
East	11846	39066	4.52	11846	33992	3.98	11846	40932	4.70	11846	40985	4.70	11846	38995	4.51
Central	9739	36030	4.96	9739	34114	4.75	9739	40685	5.44	9739	37479	5.12	9739	35928	4.95
South	12957	36943	3.96	12957	31715	3.37	12957	38166	4.08	12957	38924	4.16	12957	36711	3.93
Southwest	4803	23021	5.98	4803	22343	5.86	4803	26011	6.46	4803	23415	6.04	4803	23002	5.97
Plateau	8378	19944	3.26	8378	18225	2.92	8378	22771	3.77	8378	20085	3.29	8378	19944	3.26
Northwest	8182	23162	3.93	8182	22368	3.80	8182	26417	4.44	8182	23109	3.92	8182	23197	3.94
China	**8578**	**29800**	**4.72**	**8578**	**27607**	**4.42**	**8578**	**32976**	**5.11**	**8578**	**30785**	**4.85**	**8578**	**29727**	**4.71**

Table B.11 Organic and chemical fertilizer used per hectare, by region, under different scenarios (kg/ha)

	Baseline			Liberal			High growth			High R&D			Irrigation up		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
Organic fertilizer															
North	84	89	90	84	89	90	83	89	90	84	89	90	84	89	90
Northeast	32	33	32	32	33	32	32	32	31	32	33	32	32	33	32
East	63	65	63	63	65	63	64	64	62	63	65	63	63	65	63
Central	99	98	90	99	98	90	98	96	89	99	98	90	99	98	90
South	123	143	155	123	143	155	125	142	156	123	143	155	123	143	156
Southwest	106	106	100	106	106	100	105	105	98	106	106	100	106	106	100
Plateau	42	49	52	42	49	52	41	49	51	42	49	52	42	49	52
Northwest	34	40	44	34	40	44	34	40	44	34	40	44	34	40	44
China	**71**	**75**	**74**	**71**	**75**	**74**	**71**	**74**	**73**	**71**	**75**	**74**	**71**	**75**	**74**
Chemical fertilizer															
North	479	492	495	479	493	497	477	483	482	468	466	453	485	507	520
Northeast	203	211	215	203	211	216	202	208	210	200	205	205	205	220	231
East	543	561	568	544	562	571	543	556	560	530	530	518	548	573	588
Central	494	525	551	494	527	554	490	515	538	481	496	500	502	549	592
South	520	576	601	520	579	605	521	567	587	506	542	544	523	588	620
Southwest	294	313	330	294	314	331	292	307	322	290	303	312	296	319	340
Plateau	84	83	84	84	83	84	84	84	85	84	83	83	84	84	84
Northwest	151	154	154	151	154	154	151	151	150	149	148	144	154	162	167
China	**354**	**369**	**376**	**354**	**370**	**377**	**352**	**362**	**366**	**347**	**351**	**346**	**358**	**380**	**395**

Note: fertilizer use is measured in terms of its nutrient content, i.e. N, K_2O and P_2O_5.

Table B.12 Total organic and chemical fertilizer used, by region, under different scenarios (1000 tons)

	Baseline			Liberal			High growth			High R&D			Irrigation up		
	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030	2010	2020	2030
Organic fertilizer															
North	2275	2370	2335	2275	2370	2335	2265	2334	2285	2275	2370	2335	2275	2370	2337
Northeast	682	691	657	682	691	657	678	676	638	682	691	657	682	690	654
East	825	812	758	825	812	758	820	794	728	825	812	758	825	812	759
Central	1103	1073	977	1103	1073	977	1096	1052	949	1103	1073	977	1103	1073	980
South	1137	1214	1208	1137	1214	1208	1132	1191	1171	1137	1214	1208	1137	1214	1209
Southwest	1874	1854	1723	1874	1854	1723	1863	1825	1685	1874	1854	1723	1874	1854	1724
Plateau	43	51	53	43	51	53	43	49	51	43	51	53	43	51	53
Northwest	734	867	936	734	867	936	730	853	917	734	867	936	734	867	936
China	**8673**	**8931**	**8646**	**8673**	**8931**	**8646**	**8627**	**8775**	**8424**	**8673**	**8931**	**8646**	**8672**	**8931**	**8651**
Chemical fertilizer															
North	13049	13048	12834	13050	13067	12871	12934	12679	12258	12756	12351	11729	13203	13453	13471
Northeast	4293	4414	4444	4293	4418	4456	4268	4321	4304	4240	4290	4233	4341	4589	4777
East	7064	7042	6867	7067	7053	6903	6997	6850	6530	6892	6647	6256	7120	7192	7101
Central	5528	5774	5971	5529	5794	5998	5471	5622	5759	5386	5449	5419	5618	6033	6417
South	4804	4901	4673	4807	4922	4704	4731	4750	4392	4678	4611	4233	4835	5003	4822
Southwest	5208	5447	5674	5209	5464	5684	5169	5344	5519	5136	5279	5371	5235	5549	5848
Plateau	87	86	86	87	86	86	87	85	85	87	85	85	87	86	86
Northwest	3303	3307	3258	3300	3308	3254	3278	3226	3138	3245	3167	3039	3366	3476	3531
China	**43336**	**44018**	**43807**	**43342**	**44113**	**43958**	**42935**	**42877**	**41985**	**42419**	**41881**	**40367**	**43805**	**45381**	**46054**

Note: fertilizer use is measured in terms of its nutrient content, i.e. N, K_2O and P_2O_5.

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