China's food demand, supply and trade in 2030:
updated simulations using the Chinagro model

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The paper describes prospects and challenges for Chinese agriculture up until 2030 under different scenarios, using the Chinagro welfare model. A scenario is defined as a coherent set of assumptions about exogenous driving forces (farmland, population, non-agricultural growth, world prices etc.), derived from the literature and our own assessments. Under these assumptions, simulations with the Chinagro model address key policy issues concerning national food self-sufficiency, farm income growth and environmental pressure from agriculture. Simulation outcomes are based on 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 and the policy variants seem reassuring for China in that foreign imports remain moderate relative to the country'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. However, 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 persistent environmental pressure from nitrogen and phosphate surpluses and potassium deficits on crop land is another cause of major concern.

[1] This paper is an updated version of the presentation at the CATSEI Final Policy Forum, Beijing, November 19th, 2010.

1. Introduction

China's agricultural economy will have to cope with many challenges in the coming decades (Huang et al., 2010). Rising incomes outside agriculture and further urbanization keep on pushing up demand for animal feed and meat, while a tight energy situation creates demand for biofuel crops. At the same time, government wants to secure domestic supply of major grains at stable, affordable prices, without recourse to the policy instruments it had to give up since it joined the World Trade Organization (WTO) in 2001. Agriculture itself has to adjust as well. Mechanization will have to compensate for labor outflow and to improve labor productivity, so as to keep the fast widening urban-rural income gaps in check. Furthermore, measures must be taken to fight water shortages in the northern regions and to contain excess nutrient application and discharges of animal manure and the resulting environmental pollution.

Hence, China's food and agricultural economy has undergone significant transition in past decades that will be pursued and need careful guidance and management. This transition has been studied in two successive EU-funded projects, CHINAGRO (2001-2005) and CATSEI (2007-2010),[2] through specific studies on dedicated topics followed by more integrative investigation in a policy simulation model called Chinagro, a general equilibrium welfare model. This model was designed and constructed in the CHINAGRO project and updated and extended afterwards in the CATSEI project. Its current structure is documented in a companion paper (Keyzer and Van Veen, 2012).

Transition is of course taking place outside China as well. Since 2005, world agricultural prices became more volatile, and they are expected to remain relatively high as compared to preceding decades in view of rising scarcity of raw materials including food, feed, fuel, fibers and fertilizer, jointly often referred to as 'F5'. The FAO food price index (with base period 2002-2004) already illustrated this as it went up in real terms from around 90 at the start of the new millennium to around 180 early 2012, with peaks in 2008 and 2011 (FAO, 2011). Price rises were particularly high for maize, sugar and edible oils, all inputs into biofuels, whereas price volatility was most remarkable for milk (IMF, 2012). Although predictions of international prices show some reduction in real terms for the next decade, widely cited projections by FAPRI (2010), OECD-FAO (2011) and USDA (2011) do not expect a return to the pre-2005 levels. Hence, given these relatively tense conditions on world agricultural markets, the central question comes up whether China's ambitions can indeed be met and, if so, which pressures this will impose on other countries.

The present paper reports on the main outcomes of simulations with the Chinagro model on issues of national self-sufficiency, farm incomes and environmental pressure, for the period up until 2030, for a base run scenario as well as for three scenario alternatives, with special reference to supply and utilization as national level for the full spectrum of agricultural products, classified into 16 different food and feed commodities. Impacts on farm incomes are also discussed with a focus on direct farm earnings, even though off-farm earnings are known to contribute in a major

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[2] Cooperating partners in the CHINAGRO project were the Centre for World Food Studies, Amsterdam (SOW-VU), the Center for Chinese Agricultural Policy, Beijing (CCAP) and the International Institute for Applied Systems Analysis, Laxenburg (IIASA), which acted as coordinator. The same partners cooperated in the CATSEI project, this time with SOW-VU as coordinator, now joined by the School of Oriental and African Studies, London (SOAS), the Agricultural Economics Research Institute, The Hague (LEI), and the International Food Policy Research Institute, Washington DC (IFPRI).

way to the income of rural households. The geographical incidence of plant nutrient surpluses and deficits serves as main indicator of environmental impacts. The scenario alternatives consider consequences of full trade liberalization, enhanced irrigation and lower growth outside agriculture, respectively.

The paper proceeds as follows. Section 2 reviews current food policy concerns in China and the corresponding themes for scenario analysis with the Chinagro model. Section 3 summarizes the model's main characteristics described in full details in the companion paper. It also introduces the scenarios whose outcomes are presented in section 4 for the baseline scenario and in section 5 for the alternatives. Section 6 assesses the outcomes within the perspective of current policy debates.

2. Food policy concerns

The current transformation of China's agricultural sector began with institutional reform, viz. the introduction of the Household Responsibility System in 1979, dismantling the communes and shifting the responsibility for production decisions to farm households (Huang et al., 2010). Land tenure rights were initially granted for 20 years, later on extended to 30 years. Gradually market reforms were introduced allowing farmers to sell an increasing share of their output to private traders. China opened up to world trade via a series of successive steps towards trade liberalization, culminating in the accession to WTO in 2001. Although as a whole the farm sector was taxed until recently, as it had been during the past 2600 years, agricultural production benefitted a major way from public investments in agricultural research, rehabilitation and expansion of irrigation works, while availability of chemical fertilizers in large amounts enabled farmers to make full use of improved incentives and infrastructure.

Combined, institutional change, market reform and public investment were conducive to high growth of per hectare crop yields as well as of agricultural output in general. Furthermore, the changes made it possible for the farm sector to meet changing demands of richer consumers, who shifted away from staple foods (grains, tubers) to more 'luxury' crops (fruits, vegetables) as well as to animal products (meat, dairy, fish) following rising incomes in the non-agricultural sector. These changes in commodity baskets and the enhanced price transmission on domestic agricultural markets, led to a sustained rise in average farm income, through which rural poverty could decline steadily, while at the same time farm households could extend their earnings through off-farm work and outmigration, often up to half of their total income.

Overall, increased consumer demand was largely met from domestic production without need for sustained large food imports but with as significant exceptions various edible oils, sugar, and feed grains (soybean in particular) and fibers (cotton), whose imports have increased considerably in the last decade. Since 2004, the food-feed-fiber trade balance has even turned negative, despite fast rising exports of fruits and vegetables. Macro-economically, this deficit is no problem since the non-agricultural trade surplus is large enough. In all, China's agricultural reform is widely considered to be a success story.

There are also serious issues pending, nonetheless. One relates to the subject of *national grain security*. Chinese policy makers have been known to differ as to what extent China should rely on the world market for its grain supply (Rosen et al., 2004), and some of them have criticized the free trade provisions of the WTO accession act. For soybeans, these provisions included abolishing most import tariffs at the time of accession, which resulted in vast import volumes. For rice, wheat and maize, tariff quota were stipulated in the WTO act (with negligible in-quota tariff rates and large above-quota rates), but with 5, 7 and 9 million tons, respectively, these quota seem large, and they never became binding so far since the accession (Zhou and Kang, 2009), although recent increases in maize imports to 2 million tons (FAO, 2011) may signal future changes in this respect.

In fact, government policies aim to limit grain imports by adapting production and possibly demand by domestic measures rather than by limiting trade, which in view of the enormous domestic market, and the increasingly inelastic consumer demand would cause food prices to rise at an uncontrolled rate. After 2002-2004, when grain harvests were low, farm taxes have been abolished and replaced by a system of subsidies, which were largely provided as per hectare income support, hence obeying WTO principles of decoupling (Huang et al., 2011). Yet, some price support is maintained for grains. The total subsidy program currently amounts to around 4% of agricultural GDP, well below the upper bound of 8.5 % stipulated under WTO accession. In addition, government has exercised its right to shield the country from excessive price fluctuations on international markets, for instance by a temporary ban on rice exports in 2010 (OECD, 2011). Concerns about national grain security have kept China’s domestic biofuel targets relatively modest, and largely based on imports, with a planned increase from the current level of 1.5 million ton bio-ethanol to no more than 3 million ton by 2020, preferably produced on the basis of secondary crops. Further increase of other industrial non-food use, particularly of maize, has been put on hold, albeit that 2012 levels may reach close to 20% of maize output already.

Hence, both strong exposure to volatile world markets resulting from free trade and import dependence due to continued rise in demand for livestock products are sources of concern on the trade and demand side. There are specific concerns on the supply-side as well. We mention three, as identified in the course of the CATSEI project.

Farm size is the first. Sustained rural-to-urban labor migration has gradually created labor scarcity in some rural areas (Zhang et al, 2010) that would need to be addressed by intensified mechanization. However, the prevalence of steep slopes and the even distribution of land across households that keeps the average farm size small (about 0.6 ha), make it difficult to reap the benefits of mechanization to the full. To address this, government has recently eased the renting of land from other households.

Second, *water scarcity* has become a threat to agricultural production, particularly in the North where groundwater levels decline permanently. Therefore, large infrastructural works have been initiated to transfer water from the South to the North, while the Number 1 policy document of 2011 was fully devoted to reform and development for water conservation (CPC, 2011). It would seem, however, that expanded irrigation and water conservation will not suffice. Land use and cropping patterns will have to be reconsidered as well (IWMI, 2006).

Third, intensity of *fertilizer application* is highest in the world, reaching 450 kg of chemical nutrients per hectare arable land in 2010 (NBSC, 2011), nearly three times the world’s average. While this has contributed in a major way to China’s recent agricultural development, it also has turned into a major cause of China’s current environmental problems. Nitrogen surpluses are emitted as greenhouse gas and leach into the groundwater with a potential toxic effect. They also cause eutrophication of surface waters (Fischer et al, 2008; Ju et al, 2006). Phosphate surpluses may contribute to eutrophication as well (Le et al, 2010) and induce micronutrient deficiencies in the soil (Voortman, 2010). At the same time, and somewhat surprisingly in view of the general overuse of chemical fertilizer, potassium deficiencies persist (Tan et al, 2012). Of particular concern is the fact that in the past decade overall organic and chemical fertilizer use has increased much faster than crop yields (NBSC, 2011), which suggests a decline in fertilizer use efficiency. China's government is well aware of this negative trend and has consequently launched in 2005 its policy guideline towards 'fertilizer application based on measurement' in designated provinces. So far, this does not seem, however, to have resulted in overall increases in fertilizer efficiency, and it seems safe to state that the phenomenon of overuse is insufficiently well understood, especially considering that fertilizer is not being subsidized at present.

Besides these demand, trade and production issues the widening *urban-rural income gap* is a major source of concern, despite the fact that rural incomes have gone up considerably since the start of the reform process. The urban-to-rural income ratio was around 2.5 some 15 years ago and is currently approaching 3.5 (Huang et al., 2010). To curb this trend, government has made development of a 'new socialist countryside' one of the spearheads of its overall policies. Discussions about the desirability of further agricultural trade liberalization should also be seen against this background, as many fear that agricultural populations in the poorer, remote regions will lose from it, due to their dependence on staple crops. Hence even though China is in principle interested in pushing global trade liberalization further, it is hesitating in making further commitments in the, still ongoing, Doha Round both for reasons of income distribution and for reasons of national grain security.

These policy concerns define the policy themes of the Chinagro scenarios in this paper.

3. Scenario simulation with Chinagro

The Chinagro model is a spatially detailed general equilibrium welfare model of the Chinese economy with emphasis on the agricultural sector. Farm supply is modeled for each of 2885 counties, covering the whole of China, and for several land use types. At the same time, regional commodity markets link the county farms to the rural, urban and foreign consumers. The model distinguishes 17 tradable commodities and 8 regions. Consumption is depicted at regional level, separately for the urban and the rural populations, each of which are divided into three income groups.

Here, we summarize the main characteristics of the model. Its full structure, including the main classifications, is described in a companion paper (Keyzer and Van Veen, 2012), while the data structure is outlined in Van Veen et al. (2005). Calculations proceed in GAMS (Brooke et al, 2011), combining the GAMS solver with a dedicated algorithm for agricultural supply. The model has been designed so as to represent the following five aspects of agricultural planning in sufficient detail:

(1) the constraints placed by geophysical and natural resource conditions on agricultural supply,
(2) the market forces determining the distribution of agricultural activities,
(3) the spatial spread and social diversity of China's population,
(4) the impact of policy on farm incomes and on regional disparity,

(5) the environmental impact of agriculture.

The model is cast in the form of a single-period welfare program that is solved for selected years of simulation over the period 2005-2030, 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 2005, 2010, 2020 and 2030. With respect to validation, the model fully replicates for every county and region of China in the 2005 base-year conditions, adequately mimics changes over the period 2005-2010 and provides interpretable results until 2030.

As mentioned above, the welfare program has eight regions, with farm supply described at the much more disaggregated county level. The regions are shown in Figure 3.1. The distinction between the 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.

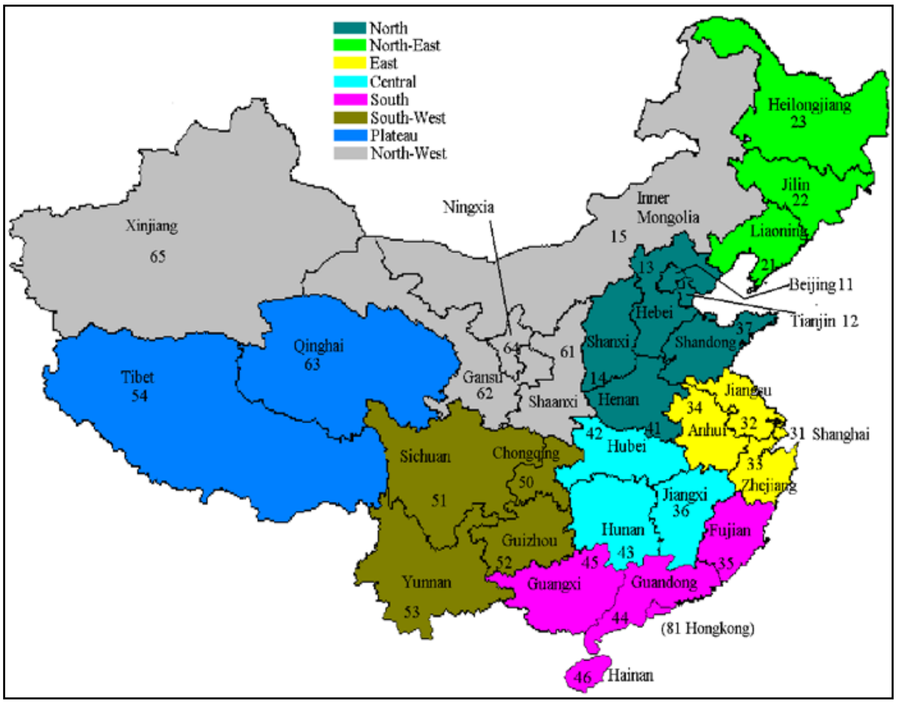


Figure 3.1 Map of China with provincial boundaries and the eight Chinagro regions[3]

Farm output is cast in terms of various activities covering fourteen types of crops and nine types of animals, whereas also related activities such as collection of household waste and supply of machinery power are included. 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

[3] Taiwan is not included in this analysis and, therefore, absent from the map.

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. Of the seventeen tradable commodities in the model, thirteen are food commodities and two are feed commodities, while one commodity (maize) is used for both food and feed and one commodity is non-agricultural.

The general equilibrium welfare model 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 behavior of foreign consumers, and (d) the balancing on the regional markets of supply and demand, with appropriate trade between regions and with the foreign markets.

Farmers maximize their revenue by optimally allocating labor and equipment to cropping and livestock systems, at exogenously specified land resources, stable capacities and levels of technology, while taking the buying and selling prices in the county as given. In addition to purchased inputs, local inputs such as crop residuals, grass, organic manure and household waste contribute to the production process. For each land use type technology is represented by a production function with two branches, a piecewise linear branch that indicates how much fertilizer or feed is required to achieve a given yield, and a Mitscherlich-Baule branch that does the same for labor. In cropping systems sown area is further allocated to crops on the basis of a nonlinear rotation cost function, while individual yield trends are linked to the development of aggregate yields by land use type. A similar approach is followed for the allocation of stable use and output to animals, by livestock system.

Consumers maximize their utility at given prices, by optimally allocating their expenditure according to a linear food expenditure system with time-dependent coefficients and quasi-linearity in non-food. The preferences of foreign consumers for net imports from China are modeled as trade welfare function that is being maximized in competition with Chinese consumers. Trade between China’s regions and with the rest of the world is cost-minimizing at given world prices and import and export tariff rates. Government tax and trade policies are imposed exogenously.

Non-agricultural supply and demand is specified by region (hence, not at county level) and largely exogenously, thus setting the level of overall economic activity the agricultural sector operates in. Also output from fishery and forestry are represented exogenously. 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 2005 price and expenditure levels.

Due to its significant geographic detail, the model can incorporate location-specific information on climate, resources and technology, while its equilibrium structure enables it to describe market clearing at different levels. Together, the decisions of producers, consumers and traders are such that at given exogenous conditions 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 program explicitly maintains material balances of nutrients, land, labor, livestock numbers and stable capacity. Regarding nutrients, net balances of N, P and K on cropland are calculated for each county as the difference between the application of nutrients via organic and chemical fertilizer (and in case of nitrogen for certain crops also via fixation from the air) and the actual crop uptake, taking into account the crop residues that remain on the land after the harvest.

A model with such a level of detail in classifications is not designed to represent truly endogenous dynamics, as this would inevitably lead to a serious accumulation of prediction errors over time. Therefore, we opted for a formulation that assumes an exogenous value for a wide range of driving variables, and provides separate static solutions for the endogenous variables for each year of simulation, 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, development of land resources and stable capacities, technical progress in agriculture, changing food preferences, trade policy and international price trends. The important role played by these driving forces requires us to make a careful and coherent specification of future trends, derived from the literature and our own assessments.

The baseline scenario until 2030 is characterized by (i) sustained growth of non-agricultural output, albeit at a lower annual rate (average of 6-7%) than the double-digit rates of recent years; (ii) moderate population growth (to 1436 million people by 2030), with urbanization rising to 60%; (iii) moderate cropland losses, relatively more for rainfed land than for irrigated land; (iv) steady improvement of yields and labor efficiency in cropping but only moderate increase of fertilizer efficiency; (v) continued intensification of the livestock sector, with higher feed efficiency but less based on residuals; (vi) gradual shift from consumption of staple food to more luxury food, also in rural areas; (vii) further trade liberalization; (viii) abolition of farm taxes; (viii) introduction of agricultural subsidies, largely untied but with some degree of grain price support; and (x) significant increase of industrial use of crop output, in particular maize and vegetable oil, but only to a limited extent for biofuel production. The trends in world food and feed prices are based on the joint projections of the UN Food and Agricultural Organization and the Organization for Economic Cooperation and Development (OECD-FAO, 2011), but with upward adjustments for grains, feed and meat. They can nevertheless be characterized as modest in terms of their assumed rise in meat and biofuel demand worldwide.

This baseline specification has been established after intensive discussions among the CATSEI project partners. It is not “business as usual” but provides a feasible picture of future developments based on central tendencies that are expected and, by themselves, considered politically acceptable. Given the policy concerns expressed earlier, the analysis of the scenario outcomes will focus on foreign trade volumes of, in particular, grains and meat, farm incomes and nutrient balances, while obviously not neglecting the consequences for consumer welfare. To gain more insight into likely impacts, three policy variants will be considered in addition to the baseline scenario:

a) *Liberal*: all tariffs on foreign trade are strongly reduced after 2010 and fully abolished after 2020
b) *Irrigup*: enhanced irrigation (location-specific), with the same total of seasonal cropland

c) *Lowgrow*: lower growth of non-agricultural incomes, with associated to it lower population fertility, reduced rural-to-urban migration and less technical progress in agriculture.

At an earlier stage, scenarios have been analyzed that focus on higher growth of non-agricultural incomes and higher agricultural R & D expenditures (Fischer et al, 2007) and higher biofuel targets, with or without use of marginal land (Qiu et al, 2008; Qiu et al, 2011). They are not repeated here.

4. Outcomes from the baseline scenario

As in section 2 our discussion starts with the growth rates in demand and supply, shown in Figure 4.1 for period 2005-2030. Growth in wheat and rice consumption is slightly negative, since demand for these staple foods has reached satiation and was partly replaced by demand for more luxury food (fruits, vegetables, meat, dairy), especially under the impact of urbanization. Yet, partly due to the grain subsidies, staple crops remain sufficiently attractive for farmers to keep production growing. Demand for maize shows a steady rise, at more than 1.5% annually, because it also includes feed and industrial use. Although maize output does also very well at close to 1.5% growth annually, this is not sufficient to keep up with demand. The same applies to the cash crops, edible oils and sugar. For fruits and vegetables, however, production grows faster than consumption, allowing for an increase in exports. Compared to the other food items, consumption of vegetables grows at a relatively low rate, since current levels of consumption are already quite high. The largest growth rates of consumption are found for meat, milk, eggs and fish, ranging from 2 to 4% annually, due to the steady increases in income. Although production of these commodities also adjusts rapidly, it is not enough to fully meet the increased demand.

Hence for most commodities, demand rises faster than production, except for rice, wheat, fruits, vegetables and fish. These trends are reflected in the net export levels for food in Figure 4.2, which shows increasing imports for edible oils (from 10 to 20 million tons), sugar (from 1 to 5 million tons), pork and poultry (taken together as white meat, and going from small exports in 2005 to 2.5 million tons of import in 2030) and, in particular, dairy (from 1 to 15 million tons). Regarding dairy, we remark that the volumes shown are expressed in their fresh milk equivalent, and correspond to far smaller quantities of the products actually traded, such as milk powder, condensed milk, butter or cheese, by a factor of five to six.

On the export side, rice exports are seen to rise from almost nothing to more than 3 million tons, wheat imports turn into exports, and exports of fruits and vegetables increase considerably, from 8 to over 20 million tons, under the qualification that other countries will not use sanitary and phytosanitary (SPS) measures as non-tariff barriers to trade to counter these exports and that China will be able to secure niches to realize its export potential of fresh as well as preserved fruits and vegetables. Fish exports remain moderate, reaching 1.8 million tons in 2030.

To reflect the present policy stance that the livestock sector will have to remain a major contributor to farm household income and employment, the scenario specification regarding stable capacities and labor migration assumes that meat demand is largely met from domestic production. Consequently, the simulation shows China increasing its reliance on the world market for animal feeds, especially because the availability of traditional feed (such as crop residuals, grass and household waste) cannot expand at the same rate as the livestock sector. Figure 4.3 shows the increases in tradable feed imports, subdivided into three commodities, namely maize, carbohydrate feed and protein feed. Carbohydrate feed covers feed types other than maize that are relatively rich in carbohydrates, such as those based on tubers and minor grains, while protein feed covers feed types that are relatively rich in proteins, such as oilseed cakes and wheat and rice bran.

The fully calibrated model confirms that in 2005 maize was actually exported, albeit at subsidized prices to get rid of excess stock. For 2030, however, the baseline scenario projects a switch to substantial import volumes, up to around 24 million tons, presuming that government tariff quotas will permit large volumes of imports at relatively low tariff rates. Imports of carbohydrate feed are relatively minor, going up from 1 to 1.5 million tons, expressed in grain equivalents, but protein feed imports are impressively large, rising from 23 to 57 million tons, expressed in term of cake equivalents, which is a large fraction of present world trade. As an illustration, for soybean cake, China's main protein feed imports, total world imports reached about 130 million tons (USDA, 2012).[4] China would depend for 60%, 30% and 43% on imports for its demand of edible oils, sugar and protein feeds, respectively. All other shares are below 20%.

Given the country's large non-agricultural trade surplus, these imports do not create financing problems for China, but import dependence and the major impact on world markets are aspects that cannot be discarded. In particular, the model predicts by 2030 an upward impact of 7% on world prices of maize and protein feeds due to the rise in China's imports of these commodities.[5] China's efforts to secure part of its agricultural imports via leasing or obtaining land in other continents (a practice sometimes indicated as 'land grabbing') can be understood in this context. On the other hand, China's additional exports will lead to some relaxation on the world markets concerned.

Turning to trends in farm revenues, we note that Figure 4.4 shows a future for livestock farmers that promises to be better than that of crop farmers. While the incomes of the latter rise on average by 2.6%, livestock farmers see their incomes rise annually by 4-7% depending on the region, leading to a total farm income growth of 3-4% for most regions. Although farm labor decreases and the incomes per laborer consequently rise at a faster rate than absolute earnings (nationwide by 4.3%), the gap with industry and services becomes larger. This trend in the income gap is a serious issue, particularly since urban incomes are already much higher than rural incomes.

Figure 4.5 gives further detail on the pattern of consumption of cereals and meat in the coming decades (of which the totals are shown in Figure 4.1 above). Figure 4.5a shows that cereal consumption in rural areas declines from 180 to about 170 kg per person per year. Urban cereal consumption is much lower at just above 110 kg, decreasing only slightly due to the impact of processed wheat and cakes. Since the degree of urbanization is mounting, average per capita cereal consumption shows a larger decline than rural and urban consumption as such, from 150 to 132 kg per person per year. For meat, changes are faster as shown in Figure 4.5b. Higher incomes

[4] Including the cake content of whole seeds, assuming a cake content of 0.82.

[5] World price reaction coefficients in Chinagro are estimated on the basis of a sample of observations generated by applying China trade shocks to the worldwide GTAP model (Hertel, 2007).

raise consumption in both rural and urban areas. By 2030, average meat consumption (excluding eggs) reaches about 75 kg per person per year (measured in terms of carcass weight), but remains far higher in urban than in rural areas (88 kg versus 54 kg).

Total calorie intake (not shown here) seems adequate on average, with 2960 kcal per person per day by 2030 in urban areas, and 2745 kcal per person per day in rural areas as compared to 2548 kcal and 2607 kcal respectively in 2005. Hence, the baseline scenario projects a moderate, satisfactory increase in energy intake, with urban consumers catching up with and eventually overtaking rural consumers.

Figure 4.6 reports on environmental pressure from cropping. The detailed representation of agricultural production in the model allows calculation of nutrient balances for nitrogen (N), phosphate oxide (P_2O_5) and potassium oxide (K_2O). On cropland, the nutrient supply comes from chemical fertilizer, organic manure of both animal and human origin, and (in the case of nitrogen) from fixation from the air and the soil by legumes. The difference between the total supply and the uptake by the crop (subtracting the nutrients in crop residuals that are recycled and remain on the land after the harvest) is defined as the net nutrient surplus. If it turns out negative, this means that the plant must have extracted additional nutrients from the soil. If it is positive, there is a potential danger of pollution.

The 2005 situation confirms the overall concerns expressed earlier, with nitrogen and phosphate surpluses and potassium deficits. As regards future trends, Figure 4.6 shows that the nitrogen surplus is slightly falling (from 155 to 140 kg per hectare of cropland), that phosphate has a steady positive surplus of around 50 kg per hectare of cropland, and that potassium is mined from the soil throughout the period, with the initial deficit of 28 kg per hectare of cropland hardly declining. Each of these imbalances is important enough to create a serious environmental challenge. As mentioned earlier, nitrogen surpluses may be emitted as greenhouse gas (nitrous oxide), leach into the groundwater with a potential toxic effect on drinking water (formation of nitrites) or cause eutrophication in surface water (due to nitrates), enhancing the concentration of algae in lakes and rivers and provoking red tides in estuaries. Phosphate surpluses may contribute to eutrophication as well, or induce micronutrient deficiencies in the soil. Sustained potassium deficits may on their part result in reduced crop yields in specific areas, since soil mining cannot be maintained forever. In short, these outcomes call for more efficient application of nutrients in farming. For phosphates, the need for efficiency is even greater, since there are serious concerns about the looming scarcity of this crucial nutrient worldwide.

These average trends are evidently far from uniform across China. Four county maps report on geographical differences underlying the averages, one for maize output (the crop with the highest growth rate), one for farm income and two for environmental imbalances. The graphs point to a high degree of spatial heterogeneity that regional development policies will have to reckon with.

Figure 4.7 shows how the growth of maize output (on average 1.42% annually, with increasing sown areas on both irrigated and rain-fed land) differs by county, and reveals steady growth throughout China. Whereas in absolute terms, more than half of the output increases are realized in the major producing areas in the North and Northeast, in terms of growth rates these regions do not stand out, with the exception of some irrigated areas in Northeast. Figure 4.8 illustrates the differences in farm income growth, with the highest rates in the regions where livestock is relatively important. Figures 4.9 and 4.10 show the distribution of the net surpluses of phosphate and potassium oxide over the counties in 2030. Not surprisingly, the national average sign is also the dominating phenomenon in most counties, although there are exceptions. The excessive application of phosphates is most severe in Center and South, while the depletion of potassium is prevalent in most regions of the country, except for South and Plateau.

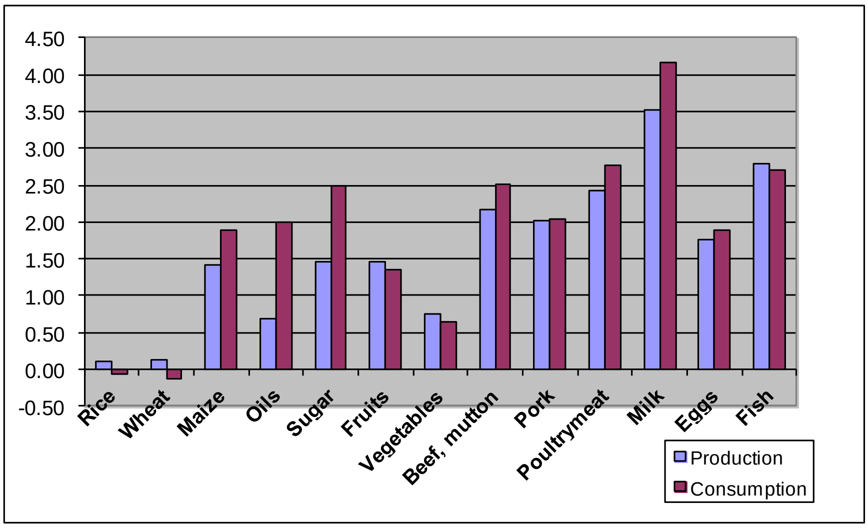


Figure 4.1 Annual growth rates of production and consumption in the baseline, in %, 2005-2030

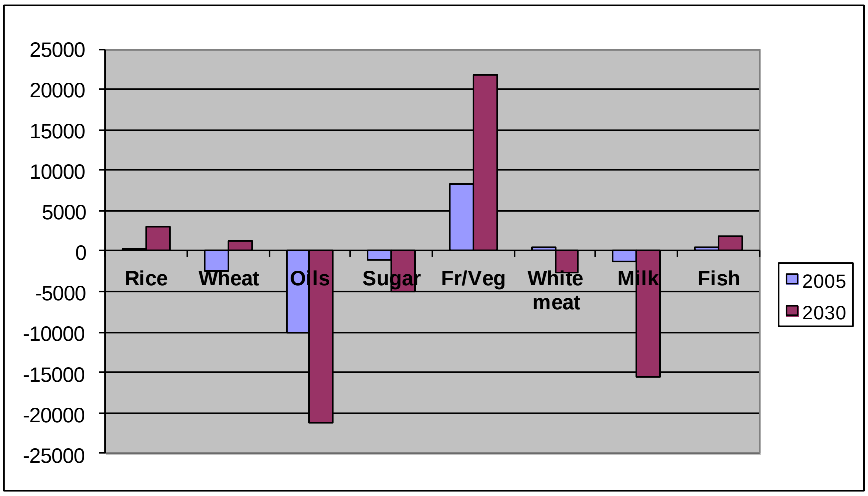


Figure 4.2 Net export levels for food in the baseline, in 1000 ton, 2005 and 2030

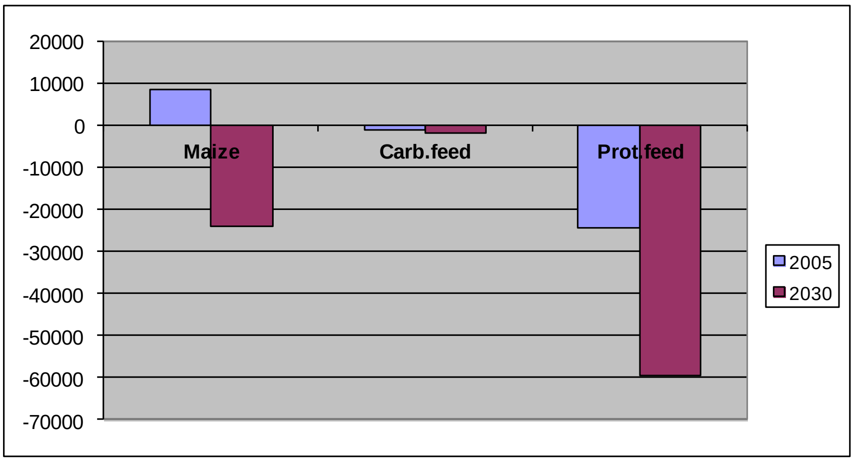


Figure 4.3 Net export levels for feed in the baseline, in 1000 ton, 2005 and 2030

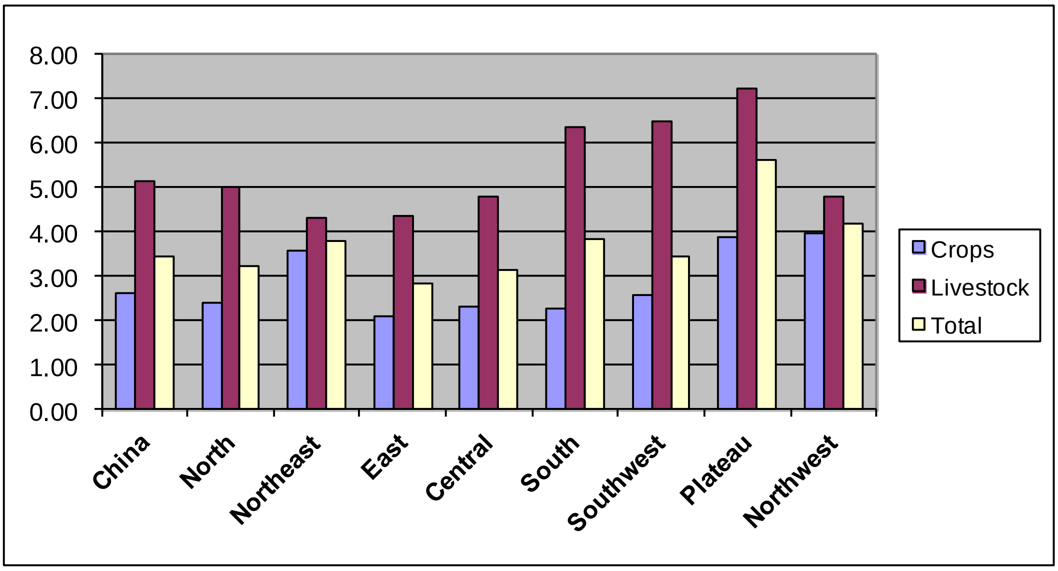
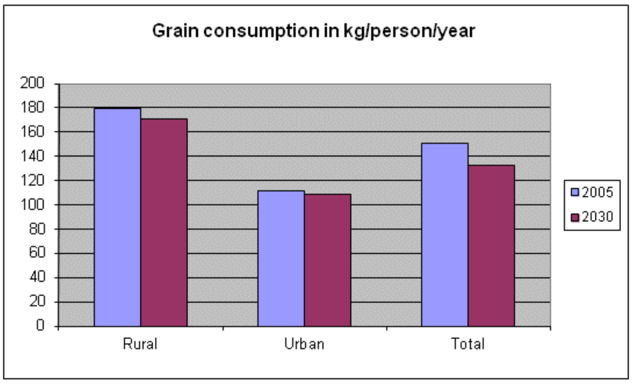


Figure 4.4 Annual growth rates of farm value added in the baseline, by region, in %, 2005-2030



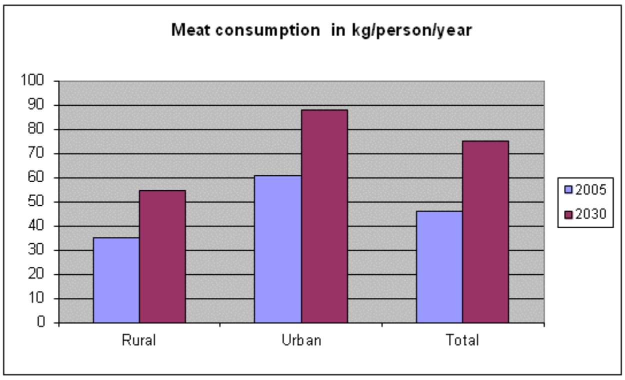


Figure 4.5 Household consumption in the baseline, in kg/person/year, 2005 and 2030: a) grain and b) meat

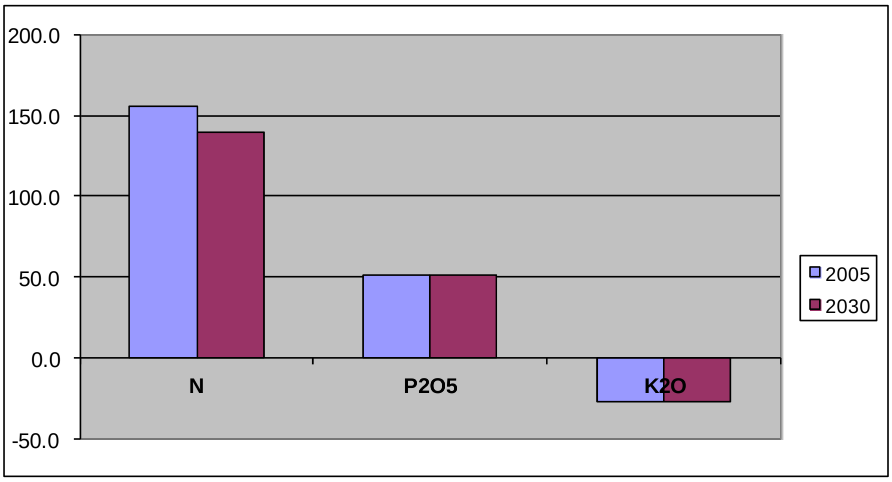


Figure 4.6 Net nutrient surpluses in the baseline, in kg per ha cropland, 2005 and 2030

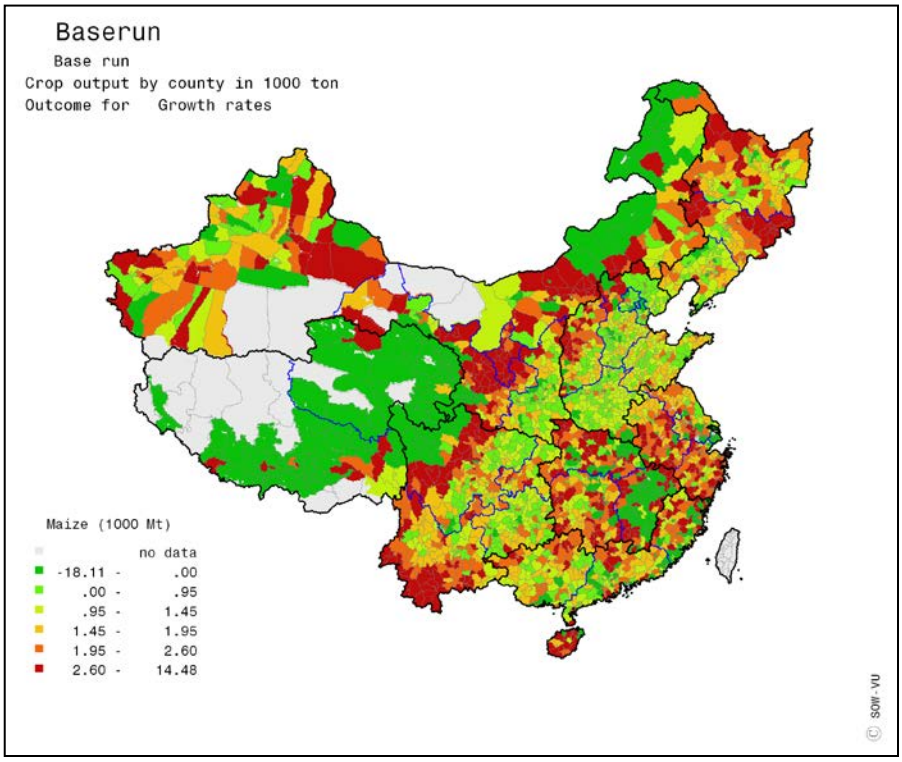


Figure 4.7 Baseline, annual growth of maize output, by county, in %, 2005-2030
'Steady growth in maize output throughout the country'

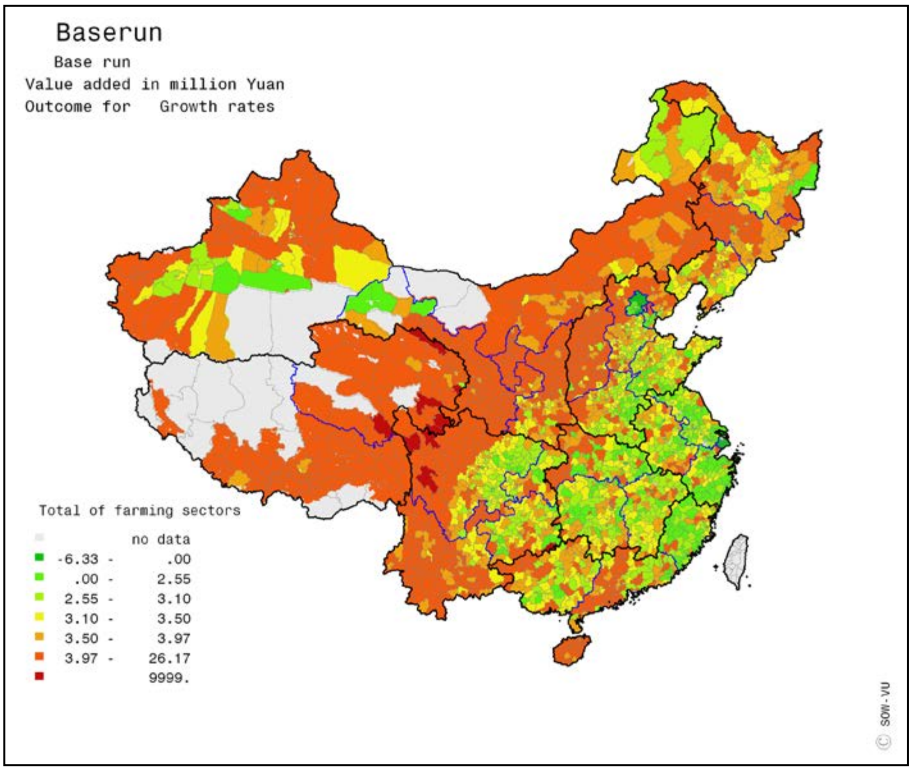


Figure 4.8 Baseline, annual growth farm value added, by county, in %, 2005-2030
'Highest growth rates where livestock is relatively important'

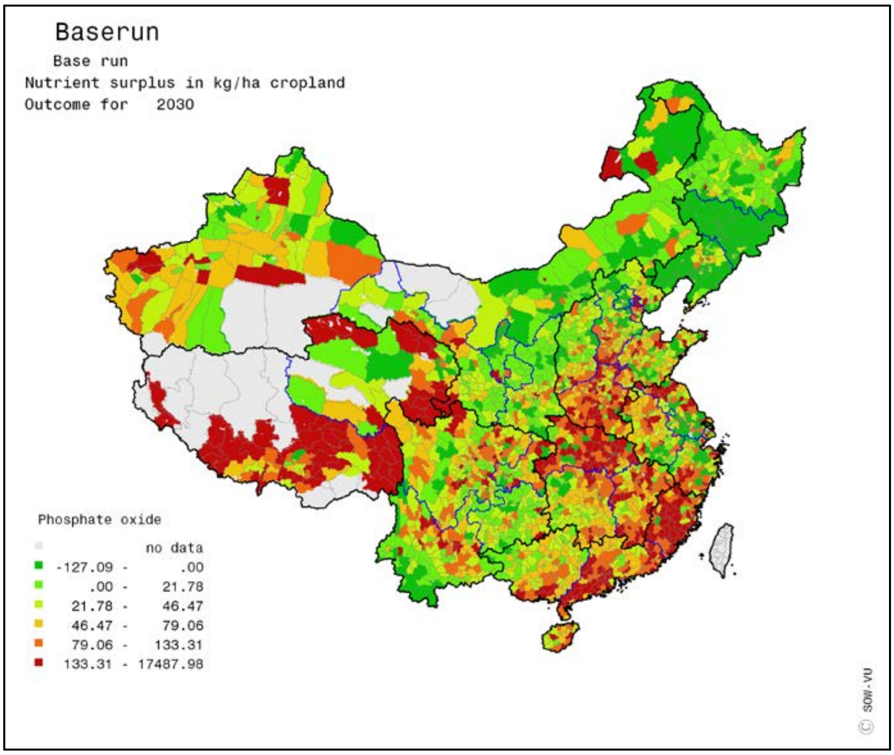


Figure 4.9 Baseline, net surplus of P-oxide on farmland, by county, 2030, in kg/ha
'Excessive application of P more common than deficit'

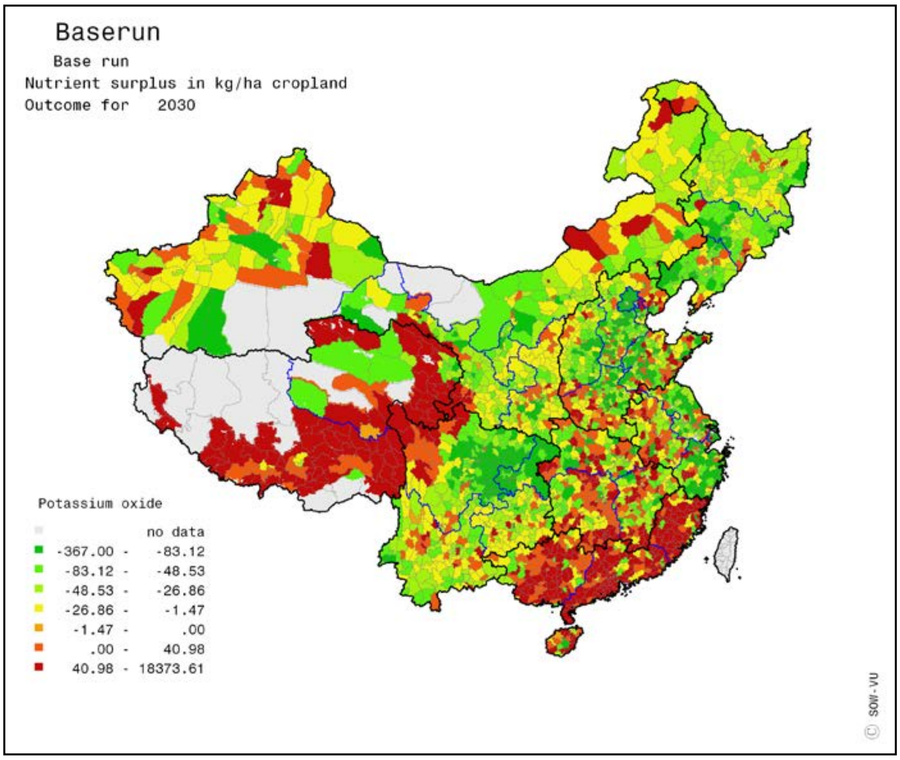


Figure 4.10 Baseline, net surplus of K-oxide on farmland, by county, 2030, in kg/ha
'Soil mining of K dominates'

5. Scenario alternatives

To assess the sensitivity of the baseline projections to policy changes, we report on outcomes of the policy variants, scenario by scenario, by means of selected figures: three bar charts that combine all scenarios in one view, and county maps that provide geographic detail for specific scenarios. Since the policy variants considered do not reveal for environmental imbalances much variation from the baseline, we limit our discussion to foreign trade, consumer welfare and farm incomes.

Liberal scenario. In this scenario both official tariffs and non-trade barriers are being reduced. As direct consequence of these reductions, imported commodities become cheaper and exported commodities more expensive, causing foreign trade to expand. For crop farmers, the price changes have mixed effects. Rice, wheat, fruits and vegetables become more profitable, but other crops in general become less profitable. Livestock farmers face both lower output (meat, milk) prices and lower input (feed) prices, but the net effect is clearly negative. Yet, the scenario shows only a limited shift away from livestock to cropping, since it assumes no change in stable capacities. Within the cropping sector, output is seen to shift in particular towards rice, wheat and vegetables.

Consumers react in opposite direction to these price changes, leading to more demand for livestock products, vegetable oil and sugar, and less demand for rice, wheat, fruits and vegetables. Demand for feed is barely affected because of the assumption of constant stable capacities. Therefore, for maize larger imports will be necessary, since its supply is generally lower (due to the price effect), whereas for carbohydrate feed and protein feed mixed trade effects would be possible in principle, in view of the composite character of these commodities.

All of these effects are somewhat tempered by the reactions of world market prices to changes in China's trade volumes, and the effect on the output of cereals appears to be rather small in the end (Figure 5.1). The impact on feed imports is relatively modest as well, with the largest increase for maize (by 2 million tons) and smaller or even negligible increases for carbohydrate and protein feed (Figure 5.2). White meat and milk imports clearly increase (by 1.5 and 3.5 million tons, respectively). Effects on farm incomes are pronounced as well. Compared to the baseline scenario, value added in the livestock sector is 3% lower by 2030. The total effect for cropping is positive, albeit only 1% leading to a negative effect of 0.7% for farming as a whole (Figure 5.3). Figure 5.4 shows the regional differences behind the change in crop value added: the counties that mainly produce rice, fruits and vegetables benefit, whereas many of the others lose. Finally, Figure 5.4 (a map by main region) reveals that consumers are the true winners in this scenario. The picture refers to rural meat consumption, but similar trends apply to most other commodities, also in urban areas.

Enhanced irrigation scenario. The scenario assumes that 5.4 million hectares of rain-fed land are converted into well-irrigated land, while the total amount of cropland remains the same. This conversion changes the resulting cropping pattern, leading in particular to more rice, wheat and vegetables at the expense of most other crops. Maize output does not change much but the share that comes from irrigated land increases to more than half. Figure 5.1 clearly confirms the effects on rice and wheat output, whereas Figure 5.2 shows that these changes also lead to reduced imports of carbohydrate feed and protein feed. The increased availability of low-quality grain and grain byproducts (mainly bran) that goes along with higher rice and wheat output, apparently dominates the reduction in feed supply caused by the decline in tuber and oilseed output.

However, the effect on farm incomes from cropping is not spectacular and even negligible (Figure 5.3). This is because increased supply leads to lower prices. The figure demonstrates what is more often found in simulations of increased technical progress in agriculture, namely that much of the benefit does not end up in farmers' pockets, but leaks away to consumers. Indeed, average energy intake in 2030 rises from 2878 to 2888 kcal per person per day. Feed prices are hardly affected, witness the negligible impact on the incomes in the livestock sector. Yet, there are regions where farmers benefit and regions where farmers lose, as shown in Figure 5.6, the latter in particular the counties with considerable areas of irrigated land and limited scope for expanding these.

Low-growth scenario. Lower growth in non-agricultural incomes means a lower increase in consumer demand for meat and milk. At the same time, the scenario assumes more labor and less technical progress in agriculture. Agricultural labor input is higher due to reduced rural-to-urban migration, which is assumed to dominate in rural areas the negative impact of lower fertility. The reduced demand for meat and milk directly lowers imports of these commodities and causes indirectly, via lower prices, a production shift from livestock to crops (for grain shown in Figure 5.1), leading to lower feed imports as well (Figure 5.2). As could be expected, the effect on value added in livestock farming is quite negative, about 9% less in 2030, but crop farmers appear to lose as well, as shown in Figure 5.3. The increased crop output is apparently not sufficient to offset the effect of the lower crop prices that result from the ample availability of crops. This scenario may issue the warning that agriculture needs strong growth in industry and services in order to achieve sufficient income growth per laborer. In the baseline scenario, agriculture already had problems keeping up with non-agriculture, and here the gap becomes even larger, despite the lower growth in industry and services. Figure 5.7 shows that also in absolute terms, farm incomes rise in few counties only.

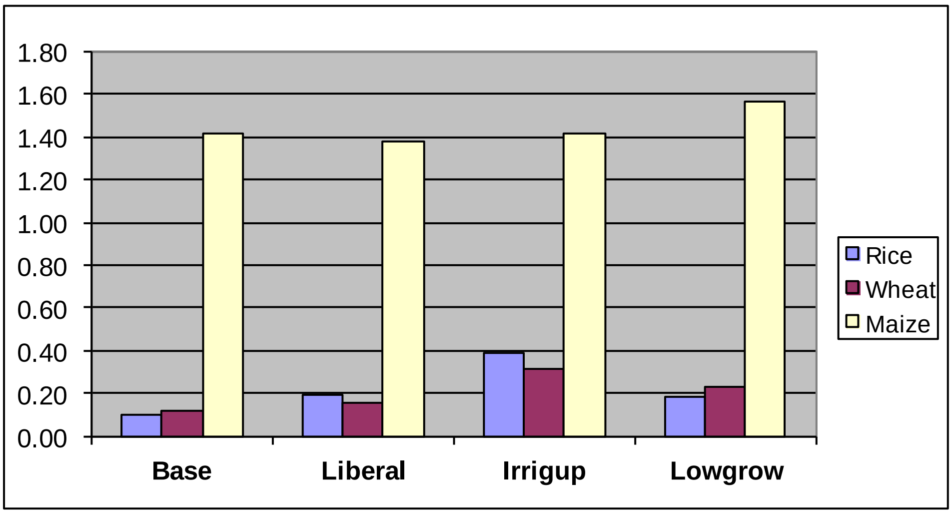


Figure 5.1 Annual grain output growth rates for different scenarios, in %, 2005-2030

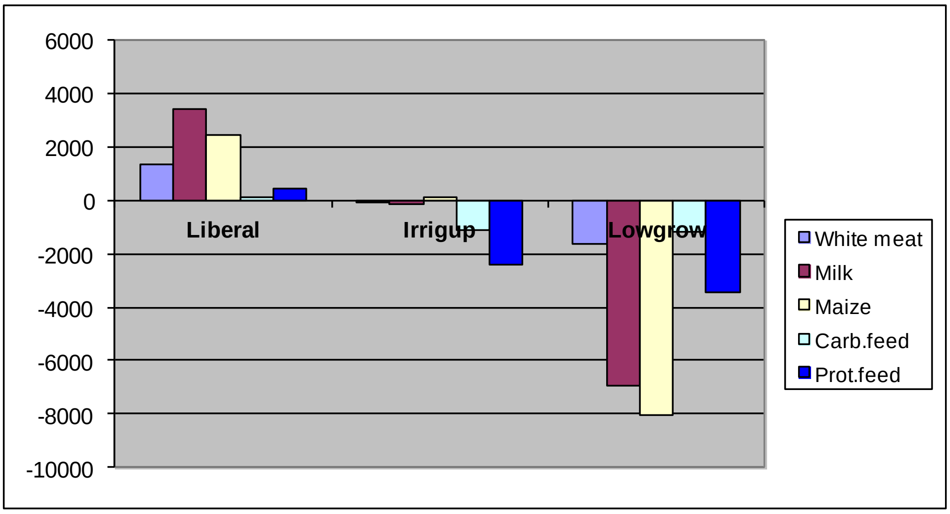


Figure 5.2 Imports of feed, milk and meat in 2030: difference from baserun in 1000 ton

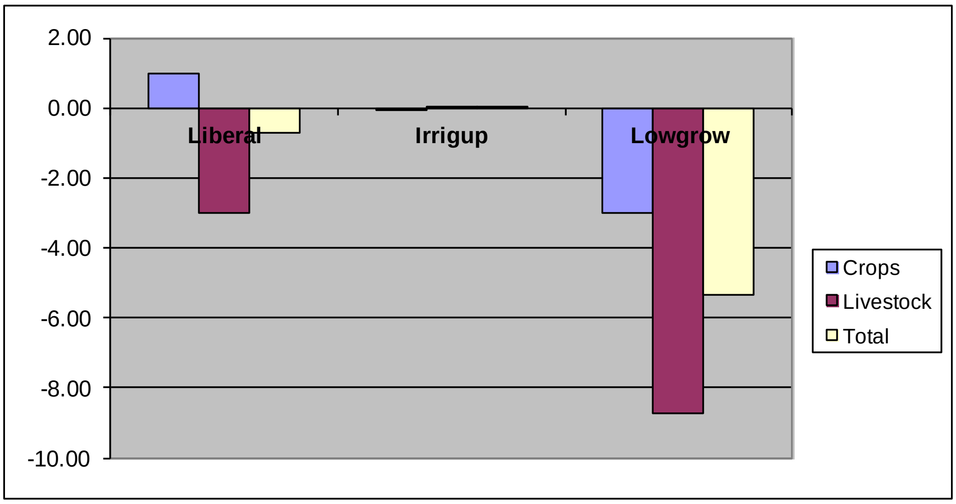


Figure 5.3 Farm value added in 2030: relative difference to baserun in %

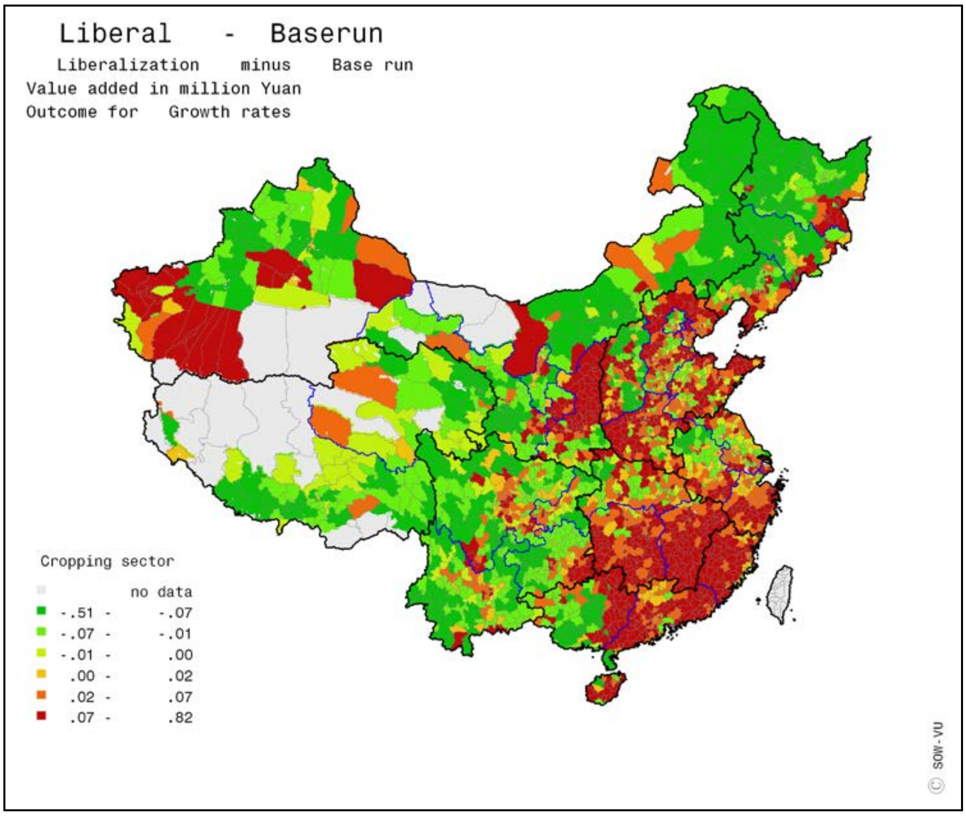


Figure 5.4 Liberal, crop value added: growth difference from baseline, in %-point
'Livestock feed shrinks whereas rice, fruits and vegetables expand'

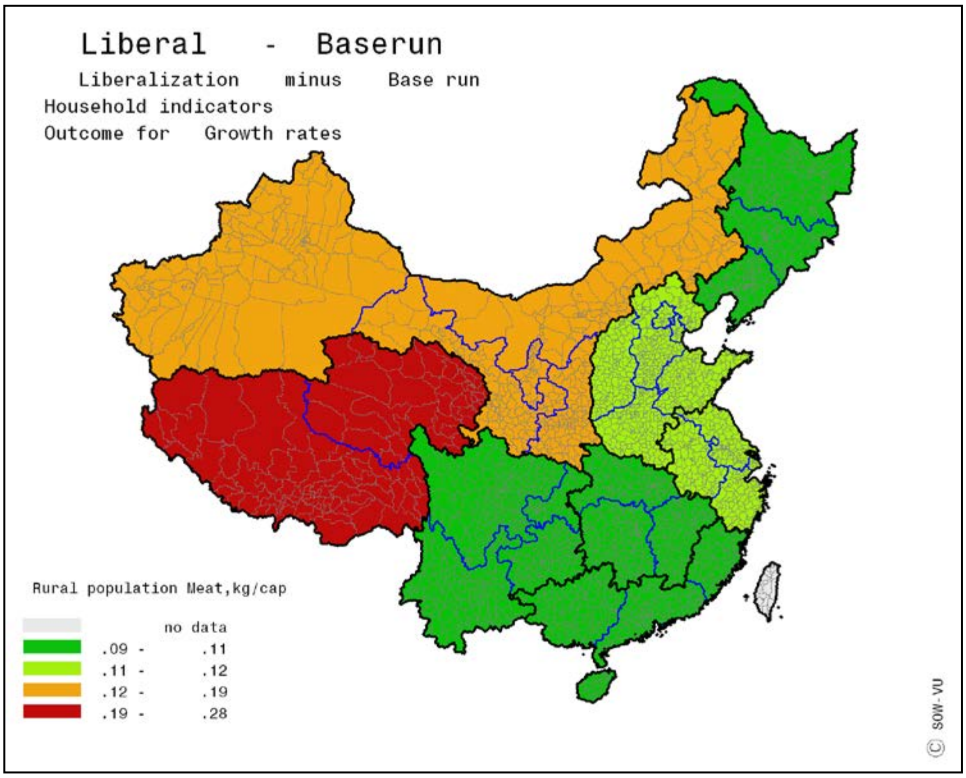


Figure 5.5 Liberal, rural meat consumption: growth difference from baseline, in %-point
'Rural consumers gain from lower prices'

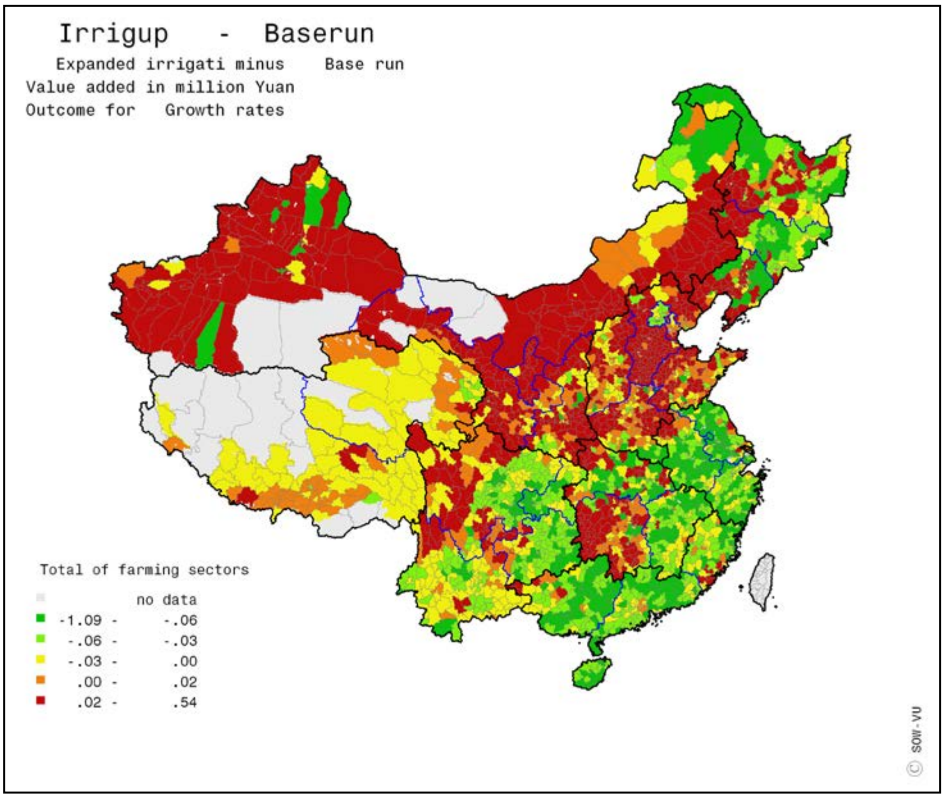


Figure 5.6 Enhanced irrigation, farm value added: growth difference from baseline, in %-point
'Areas with much existing irrigated land and little new investments lose'

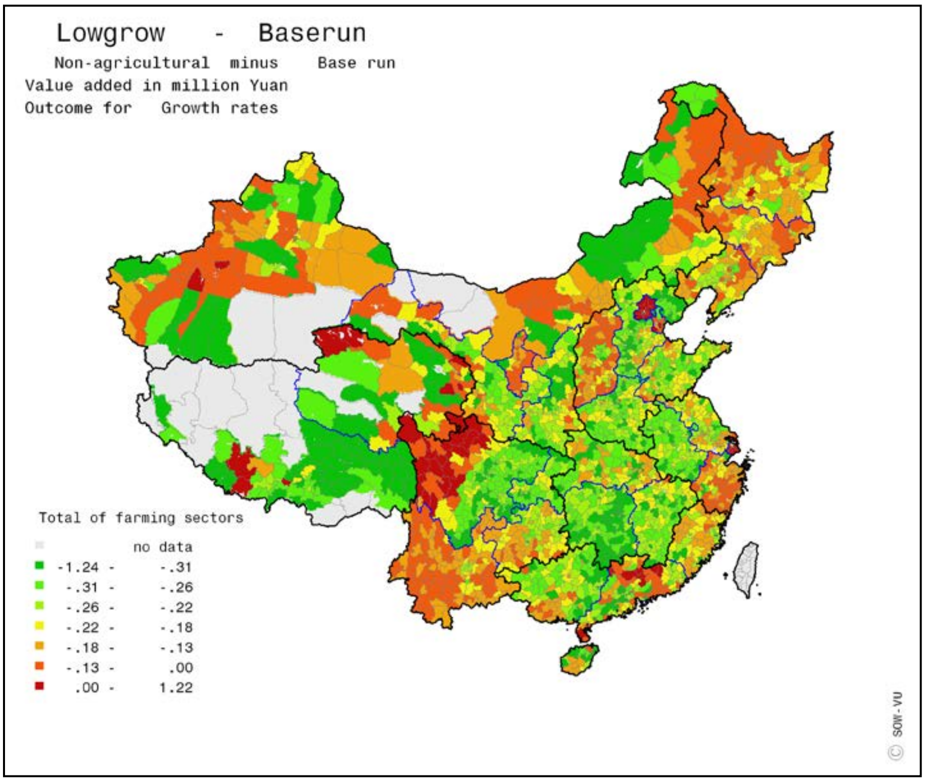


Figure 5.7 Scenario with low growth, farm value added: growth difference from baseline, in %-point
'All lose, except counties where higher labor supply compensates for lower prices'

6. Conclusions

The outcomes from the baseline scenario and the policy variants seem reassuring for China in that foreign imports remain moderate relative to the country'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. However, 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 persistent environmental pressure from nitrogen and phosphate surpluses and potassium deficits on crop land is another cause of major concern.

More specifically, regarding import volumes, the conclusion would seem to be that China is likely to become an even greater importer of vegetable oils and protein feeds than it is today, and will significantly expand its imports of maize for animal feeds. This will definitely increase pressure on the world markets of these commodities but the effects remain limited since China's agriculture itself adjusts as well. We note, however, that an expansion of the currently modest biofuel targets would aggravate this problem (Qiu et al, 2008).

For wheat and rice, major imports are not foreseen. Because of the steadily rising incomes, demand will shift away further from staple food and domestic farmers will be able to ensure sufficient supply, especially if government pursues its current policy of limited grain output support. China may even turn into a modest structural exporter of wheat and rice.

Regarding imports of livestock products the situation is much less clear. Since livestock products remain a major source of farm income, government may want to continue its policy of producing most of the meat domestically, while focusing its efforts on the reduction of the associated hazards for human health and the environment. For dairy products the options are even more diverse, due to the ample availability of grazing land, albeit not always in the proximity of cities. This finds expression in widely different import levels of dairy under various scenarios.

On the export side, the opportunities for fruits and vegetables stand out both as agricultural export commodities and as a source of rural income, which is also due to the dietary shift away from staples. While it seems clear that China's foreign competitors, Europe in particular, currently enjoy technological advantages and benefit from a mild climate, China can offer a rich variety of products, many of which are new on the international market. It would seem that major two-way traffic may emerge in horticultural products generally, and that there is broad scope for joint ventures.

Concerning farm incomes, the results emphasize that the farm sector needs high growth outside of agriculture, not only because of the high fraction of off-farm income in total farm household income, but also because of the crucial contribution of livestock to the growth of these farm incomes. Other policy options can on their own not compensate for high growth outside agriculture, which in itself increases the rural-urban income gap, a basic dilemma which this study could not resolve…

Under high growth, further trade liberalization favors consumers but it also hurts farm incomes on average. This illustrates the difficult choice between economic efficiency and poverty alleviation that agricultural policy makers often face. Also under enhanced irrigation, farmers see their prices drop, a common finding in scenarios that improve technical opportunities without expanding the outlets. A program to increase biofuel output would not help the farm sector either, not even when the additional crop is produced on new marginal lands (Qiu et al, 2011). This is because such a program will increase the feeding cost, and hence hurt livestock farmers.

Regarding nutrient balances, the outcomes confirm that nitrogen and phosphate are generally oversupplied, while potassium is increasingly mined from the soil. The surpluses and deficits are persistent and pose serious environmental threats. The policy variants considered in this paper reveal that without targeted fertilizer policies breakthroughs will not be achieved. Therefore, the outcomes univocally call for more efficient nutrient application. The challenge is to design fertilization strategies with higher utilization of organic manure and more recycling of crop residuals while at the same time maintaining current yield levels.

Apart from these broadly formulated conclusions, the simulations also point to the prevalence of geographical differences and, hence, to the need for regional development plans in addition to country-wide policies. The variation in the intensity of nutrient surpluses and deficits is an obvious point in case, as well as the differences of effects across poor segments of the rural population in remote areas. However, a similar message applies also, for instance, to further intensification of livestock farming. Relegation of such operations to regions of low population density may reduce the danger of pandemics, but these regions may find it harder to compete with imports, particularly for deliveries to coastal cities.

Regarding topics for further research, for trade options to raise dairy output in China stand out, as well as options to export more vegetables; for the social aspect the impact of changing rural age profiles on labor availability seems a major upcoming issue, and for the environmental aspect the fertilizer challenge needs to be addressed.

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