



THE ROLE OF AGRICULTURE IN A MODERNIZING SOCIETY

FOOD, FARMS AND FIELDS IN CHINA 2030

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THE WORLD BANK

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Food, farms and fields are the three evolving challenges of agriculture across the world. China has successfully addressed its “food problem” after adopting the reforms in 1978, but is increasingly faced with the “farm problem” in terms of earning a comparable living in farming, and the “field problem”, namely the long term sustainability of agricultural land. This report provides a vision of China’s modern and commercial small-holder agriculture in 2030, and outlined recommended actions to achieve the vision in six broad areas of the food security strategy, factor markets and empowerment of smallholders, provision of (rural) public goods, rural incomes, agricultural environmental management, and climate change mitigation.

For more information and to view the full China 2030 report, please visit
<http://www.worldbank.org/en/news/2012/02/27/china-2030-executive-summary>

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ACRONYMS

CGIAR	Consultative Group on International Agricultural Research
ET	Evapo Transpiration
FAO	Food and Agriculture Organization
FIP	Farmland Improvement Project
FPA	Farmer Professional Association
FPCL	Farmers Professional Co-operative Law
GDP	Gross Domestic Product
GM	Genetically Modified
GMO	Genetically Modified Organism
GTAP	Global Trade Analysis Project
IFPRI	International Food Policy Research Institute
NDRC	National Development and Reform Commission
PSE	Producer Support Estimate
OECD	Organization for Economic Cooperation and Development
RCCs	Rural Credit Cooperatives
TFP	Total Factor Productivity
WTO	World Trade Organization
mmt	million metric ton

1 US\$ = 6.3 RMB (or Yuan) (Sept 2011)

EXECUTIVE SUMMARY

Food, farms and fields—the three (evolving) challenges of agriculture. Across the world, feeding the country, generating decent and comparable livelihoods for its farmers, and sustainably managing the natural resource base are the three quintessential functions of agriculture. They are here dubbed agriculture’s food, farm and field problems.

China’s success in addressing its “food problem” after adopting the reforms in 1978 has been nothing less than remarkable. Grain output (rice, wheat and maize) has almost doubled and most hunger has been eliminated.

But earning a comparable living in farming has become increasingly challenging (the “farm problem”). Average rural incomes rose substantially—from 952 Yuan per capita in 1980 to 5,919 in 2010 (in constant 2010 Yuan). But urban incomes rose even faster, with the real income gap between average urban and rural income rising exponentially (Figure A). This has been undermining social cohesion and has instigated China to shift from taxing agriculture to subsidizing it. Similar policy shifts have historically been observed across developed countries in an attempt to stem the rising rural-urban divide.

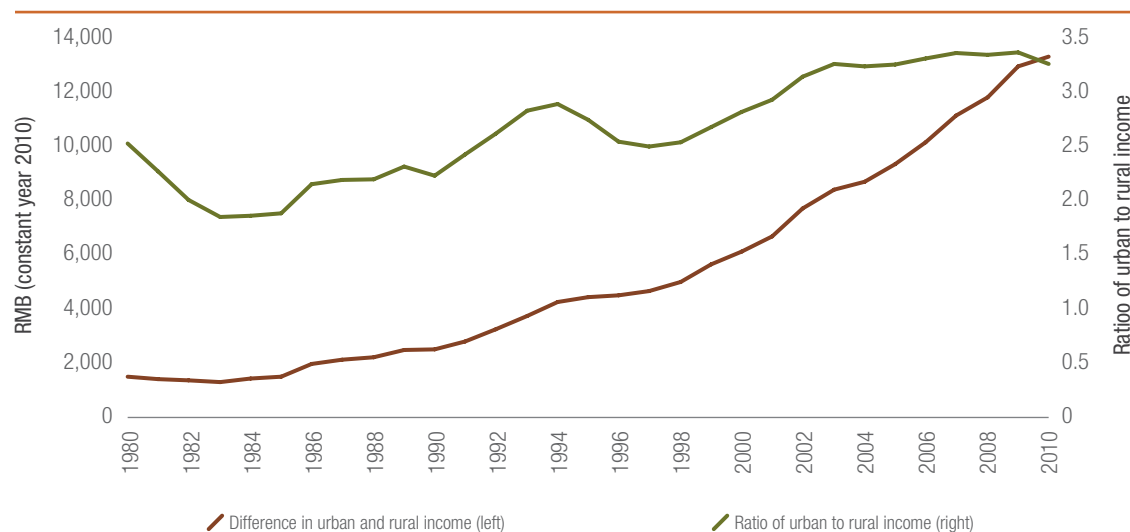
Finally, the long-term sustainability of agricultural land (the “field problem”) is increasingly being questioned. Countries’ resolve to address first the food and then also the farm problem, have often led them to overexploit their natural resource base. But, as they develop and competition over land and water increases, pressure on agriculture to reduce its environmental footprint, usually goes up, giving prominence to tackling agriculture’s “field problem”.

The relative importance of agriculture’s three problems in policymaking thus evolves during the course of development away from the food to the farm and field problems. This shift has however recently been compounded by a resurgence of the “food problem”, as global supplies struggle to keep up with demand. Against this background, the following vision for China’s agriculture is advanced.

China’s agriculture anno 2030 – A Vision. China’s agriculture anno 2030 will be predominantly a modern commercial smallholder agriculture that ensures self sufficiency in cereal food (rice and wheat), but not in cereal feed (maize and soybeans). The sector will maximize

FIGURE A

THE DIVERGENCE BETWEEN AVERAGE PER CAPITA URBAN AND RURAL INCOME CONTINUES ITS EXPONENTIAL RISE



Source: NBS (2010 and 2011).

rural employment opportunities in labor intensive high value agricultural products and act as a diligent custodian of its precious natural resources.

Achieving this will be no small feat. Rising demand for feed grains and high value agricultural products following dietary change, rapidly evolving production cost structures and shifting international, ecological, and agro-climatic environments are introducing new economies of scale, international competition and uncertainty that pose important challenges to grain production and the current smallholder farm model. But, they bring also new opportunities.

Drivers of past success. Over the past three decades China's agricultural sector has expanded substantially and diversified beyond grains. Its gross value of output (in constant prices) quadrupled. Livestock and aquatic products now contribute about two fifths of the gross value of output, compared with less than one fifth in 1978. The production

of this massive amount of agricultural output takes mostly place on fragmented plots on small smallholder farms, which until the early 2000s were still declining in size. Land saving technological change (improved seeds, chemical fertilizer) coupled with expansion of irrigation has been driving output growth, aided by liberalized input and output markets. However, with food supply constraints growing and demand rising, China's current food policies, smallholder farm structure, and intensified production model are being tested.

Cereal self sufficiency model challenged.

Rising scarcity and degradation of water and land, growing competition for labor, and a changing climatic environment are pushing up domestic production costs and risks, at the same time as the demand for land and water intensive feed cereals (maize and soybeans) is also growing rapidly. This strong demand, linked to China's shift toward a more protein-rich diet, in the face of growing constraints on supply, has resulted in upward pressures on domestic food prices. The food problem

CHINA'S AGRICULTURE IN NUMBERS – SUCCESSES, CHALLENGES AND PROSPECTS

The following striking statistics help paint the emerging new reality for China's agriculture.

1. For the past three decades (1978–2009), China's agricultural GDP has been growing annually at an unparalleled 4.5 percent on average. This has been a most important, though still widely underappreciated contributor to reducing China's number of \$1-day poor people by half a billion between 1978 and 2004.
2. Growth in total factor productivity, advancing at about 2 percent/year, has been driving agricultural growth, first through institutional reforms (the household production system), later through land saving technologies.
3. In the process, China's agriculture diversified substantially, in line with dietary change. Livestock and fishery and aquaculture production made up almost half of agricultural GDP in 2005 (35 and 10 percent respectively). In 1978, 82 percent of agricultural GDP came from crops.
4. Looking forward, the demand for grains will be increasingly driven by the demand for cereal feed (maize, soybeans) for China's growing dairy and meat production. Annual meat consumption per capita is expected to increase from 53 kg in 2010 to 73 kg in 2030, up from 25 kg in 1990. Income elasticities for vegetables and fruits (0.3–0.5) are also positive. In contrast, those for rice and wheat are negative in urban, and close to zero in rural settings. Growth in overall rice and wheat demand is expected to level off between 2025 and 2030.
5. China has about 20 percent of the world's population, 35 percent of the world's agricultural labor force, but only 11 percent of the world's agricultural land, and less than 6 percent of its water resources. Its international competitive advantage thus lies in the production of labor intensive high value products (fruits and vegetables, meat, dairy) and not in land and water intensive grain production.
6. WTO accession and Renminbi appreciation are aligning China's international trading patterns with its comparative advantage, with especially imports of land and water intensive grains increasing rapidly, somewhat compensated by rising exports of labor intensive horticulture. Soybeans imports rose from 10 mmt in 2001 to more than 50 mmt in 2008–2010.
7. The agrarian structure has been dominated by small fragmented family farms, with farm sizes averaging only 0.6 ha, divided across 4 to 6 non-contiguous plots. Equal land distribution has been an important factor in agriculture's success in reducing China's poverty. But, the viability of smallholder agriculture is increasingly challenged, as rural wages, international competition and climatic uncertainty are rising fast.
8. China's objective of being (95 percent) self sufficient in rice, wheat and maize is being challenged, as reflected in food price inflation and the emerging import of maize after many years of being a maize exporter. It also raises the prospects of a subsidy trap. Input subsidies have risen sevenfold between 2006–2010 and producer support in 2010 was estimated at 17 percent of gross farm receipts. This is the highest ever in China since 1978, even though it is considered mainly non-distortive and still only slightly above half the OECD average.
9. The potential of being able to reduce fertilizer use by 30 percent without reducing output provides important cost saving prospects to resolve the food, farm and field problems. There is also vast potential to improve the low efficiency of current water use, which in grain production is only half of that in the developed world.
10. China is betting largely on biotech to keep its TFP growth in agriculture up, with its massive past investments being supplemented by the 2009–2020 Special Program of 26 Billion Yuan. It has further expanded investment in rural education and roads to stem the rural-urban and regional divide.

is resurfacing with the domestic (95%) grain self sufficiency model increasingly being challenged, especially as WTO accession and Renminbi appreciation are also making

cereal imports more competitive. Bridging the domestic feed grain gap through trade, as already practiced through the rapid expansion of soybean imports, provides one alternative.

The dramatic increase in its imports has also helped mitigate the “field problem”, as soybean is a rather water intensive crop. Whether to relax the grain self sufficiency objective also for other land and water intensive feed (and/or food) grains such as maize, presents an important policy choice.

The smallholder model under pressure.

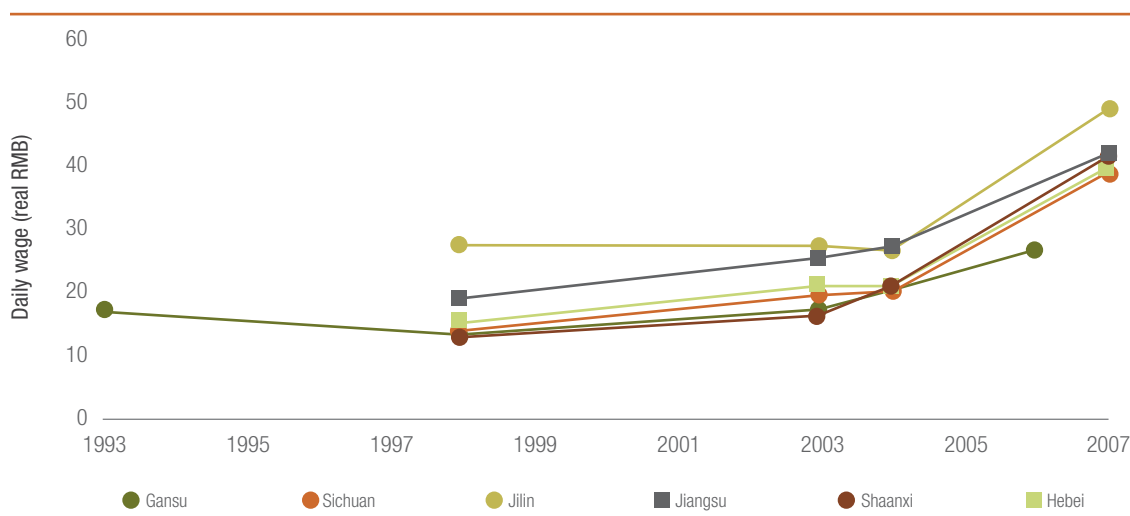
The rapid decline in the agricultural and rural labor force, following the ageing of the rural demographic and urban migration, especially of young males, is pushing up rural wages (Figure B). This challenges the smallholder farm model. Smallholders must expand to generate earnings comparable with off-farm employment as well as to capture the economies of scale from mechanization following the substitution of capital for labor. These pressures are even larger in the mountainous area, where many of the poor live and where opportunities for mechanization and land consolidation are more limited. They exacerbate the existing farm (income) problem, while the field problem lurks in the background as over use of chemicals is polluting waters and reducing soil fertility, especially in China’s grain baskets.

Urbanization also provides opportunities. Urban diets are more diversified and much less intensive in food grains (rice and wheat). This alleviates some of the supply side pressures on maintaining cereal self sufficiency. The rising demand for high value agricultural products (fruits and vegetables) further opens up opportunities for smallholders. High value products are more labor intensive to produce and generate a much higher return per ha. This helps in addressing the farm problem (in addition to migration and social safety nets), provided appropriate institutions are developed to link smallholders into the increasingly demanding value chains. The latter have arisen to capture the economies of scale in processing and marketing and to address rising demands for quality and food safety.

Towards a modernized commercial smallholder farming system. To achieve the vision of China’s agriculture anno 2030 and create a modern, commercial smallholder agriculture that adequately addresses the food, farm and field problems, requires actions in six broad areas:

FIGURE B

RURAL DAILY WAGES (REAL YUAN) HAVE RISEN SHARPLY SINCE 2003



Source: Zhang, Yang and Wang (2011).

1. revisit China's food security objectives—in particular, self sufficiency targets for maize;
2. rationalize factor markets and use institutional innovations to empower small-holders;
3. continue to strengthen the provision of rural public goods—agricultural technology, rural education and infrastructure, and food safety;
4. support rural incomes while avoiding the subsidy trap;
5. improve agricultural water and animal waste management;
6. manage risks better—adapt to and mitigate the effects of climate change.

Recommended actions in each of these are summarized below.

1. REVISIT THE FOOD SECURITY OBJECTIVES—PARTICULARLY SELF SUFFICIENCY TARGETS FOR MAIZE

China's approach to food security should allow greater import reliance for maize, thereby simultaneously addressing rising water scarcity. Like many countries, China sets a premium on food sovereignty, i.e. maintaining independent control over its food supply, typically sought through grain self sufficiency coupled with large buffer stocks. Rising domestic supply constraints and international competition render this increasingly challenging. Greater reliance on the world markets for maize, in analogy with soybeans, and combined with continued investment in TFP growth (e.g. GM maize), presents itself as a valid alternative to simultaneously address agriculture's food, farm and field problems. There is little room for land expansion and with a crop water requirement

of about 850 m³/ton output, maize is also a large user of water (Figure C), like soybeans, which requires about 3200 m³ of water per ton output.¹ Importing soybeans and maize thus equates with importing vast amounts of water, giving rise to a virtual trade in water. It can relieve pressures on the water tables in the northern plains, where water scarcity is felt most. More erratic weather patterns following climate change also increases the need for occasional reliance on the world market. Finally, to keep farmers in grain farming, farm consolidation will be needed to enable an income from grain farming compared with other crops or off-farm activities. This will be a slow and protracted process given the high transaction costs involved in exchanging land, even when factor markets are completely undistorted. Feed grain imports would still enable domestic livestock production, which is more labor intensive and remunerative, providing an important opportunity for addressing the farm income problem.

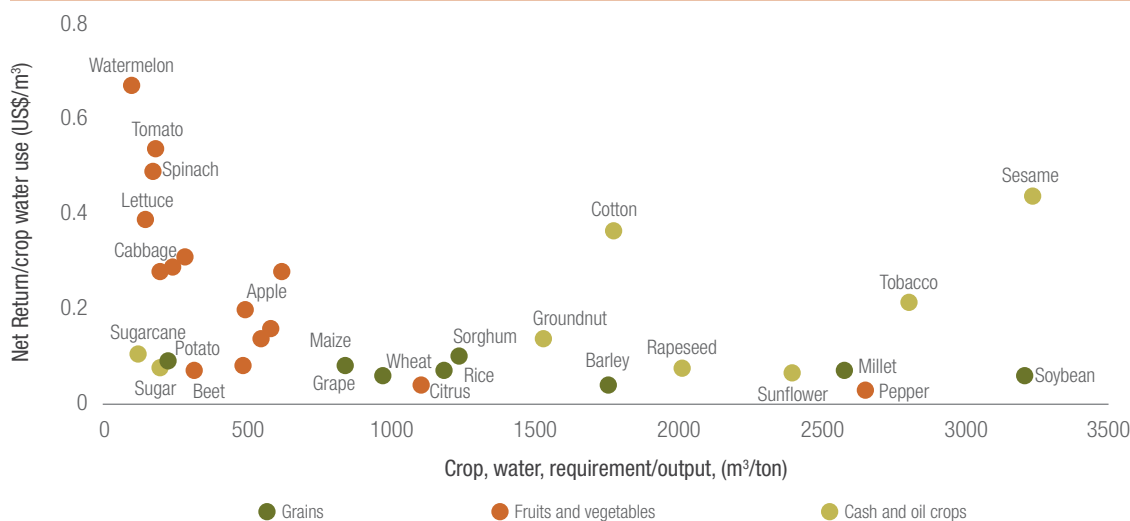
But can the markets be relied upon to deliver the necessary maize supply at relatively stable prices? Being primarily an animal feed, the political sensitivity of maize is less than that of rice or wheat, the core staples. Alternatives to maize are available, such as domestic and imported non-grain feeds (e.g. less water intensive potatoes and cassava). Second, risks can also be diversified through support to international agricultural research centers and development assistance, especially in Africa, but also in other countries with under-utilized land potential.

Third, from China's perspective, the reliability of world markets is somewhat endogenous, in that it results from coordination failure among its major players, of which

¹ The net return per m³ of crop water requirement is similar to the other core grains (rice, maize, wheat), but only at most half this of the other vegetables/fruits (except citrus).

FIGURE C

GRAINS (ESPECIALLY SOYBEANS) HAVE MUCH HIGHER CROP WATER REQUIREMENTS THAN FRUITS & VEGETABLES AND MUCH LOWER NET RETURN



Source: Liu, Zehnder and Yang, 2007.

Note: crop water requirement refers to crop evapotranspiration accumulated over the growing period of the respective crop (Chen et al., 1995). The water requirement for rice includes evapotranspiration and percolation. Net return refers to the difference between total revenue and material costs; labor cost is not included. Yield and price data for grains are based on 1999–2001 averages from the National Bureau of Statistics and FAOSTAT for other crops.

China is one. The typical response to commodity price shocks has been for exporters to impose export restrictions, while importers lower import tariffs. These actions boost world prices higher than the initial shock itself would do, leaving everyone worse off. This should provide enough motivation to WTO members to negotiate a collective agreement to limit the extent of price-insulating policies, benefiting exporters and importers alike. As a 10-year member of the WTO, and the second-largest economy in the world, this presents an opportunity for China to exert a positive influence on global economic governance.

Fourth, if maize export expansion was pursued gradually and transparently, it would provide the world's production systems time to adapt and avoid large disruptions. To help the global production system respond, China could also invest in international agricultural research centers and African agriculture more broadly. Most recent simulations using the computative general equilibrium model Chinagro II suggest that world feed prices (including maize) would increase by only 5 percent by 2030 if China were to expand its imports of maize and other animal feed according to the model's predictions.² Given the economic and

² In this scenario, the increase in maize import is predicted at (only) 16 mmt, less than 10 percent of China's 2010 maize consumption of 176 mmt, while rice exports would rise from almost nothing in 2005 to close to 3 mmt in 2030 and domestic wheat production would meet domestic demand. Put differently, the objective of 95 percent self sufficiency for rice, wheat and maize in the aggregate would actually still be reached in this scenario, even if not for each of the three cereals separately (Keyzer and van Veen, 2010). However, the scenario also predicts substantial imports of animal feed other than maize. Imports of other feed rich in carbohydrates (such as tubers and minor grains) would go up from 1 to 14 million tons (in grain equivalents) and

ecological cost pressures on China's domestic cereal production, the option of a gradual, predictable and moderate increase in China's maize imports should be explored further, including through additional modeling and scenario analysis.

Continue providing income security to address remaining pockets of food insecurity and forcefully tackle issues of micro nutrient deficiency.

Despite remarkable success in securing national supplies and a massive reduction in poverty, still 36 million people were living on less than US\$ 0.57/day in 2009, i.e. struggling with the basic needs of food and clothing. (When the poverty line was officially raised in 2011 to about \$1.8/day, the estimated number of poor increased to over 150 million.) In addition, micro-nutrient deficiencies rates (especially anemia) of up to 40 percent have been reported among rural elementary school children, substantially reducing their educational performance. Strengthening income generating activities in traditional poor area development programs and continuing to expand social protection programs in lagging rural areas (including through the rural 'dibao' income transfer program to target those unable to work) are important steps in tackling the deep seated pockets of food insecurity. But this effort also requires better household proxy targeting, as many food insecure now also live outside the western provinces and mountainous and ethnic minority areas, where food insecurity and extreme poverty has traditionally been concentrated. Targeted nutritional supplementation at school and nutritional sensitization campaigns can redress micro-nutrient deficiencies and improve educational performance.

2. RATIONALIZE FACTOR MARKETS AND USE INSTITUTIONAL INNOVATIONS TO EMPOWER SMALLHOLDERS

Rationalization of factor markets (land, labor and capital) will facilitate land consolidation and the creation of a commercially viable smallholder agriculture. Chinese farms must grow in size in order to remain intersectorally and internationally competitive, as has been historically observed in other high income countries. Given current farm sizes, rising total factor productivity in agriculture alone is unlikely to be sufficient to close the income gap with non-agriculture. China's WTO commitments further limit the scope for raising farm incomes through increased protection at the border. Creating commercially viable smallholder agriculture will entail institutional innovations in the land, labor and rural capital markets and an appropriate urbanization process. The balancing act is to accommodate land consolidation and labor movements so as to remain self sufficient in the core staples (rice and wheat) at internationally competitive prices (the food problem), while at the same time maintaining commercially viable livelihoods for a sufficiently large group of smallholder farmers to stem the growing rural-urban divide and maximize poverty reduction (the farm income problem). Indeed, given the current initial conditions, China's farming landscape will still be largely dominated by smaller holdings in 2030, by any international standard. And that does not have to pose an economic problem.

Fostering land rental is the most practical way forward in the near and medium term, while reforms in private land use

imports of other protein rich feed (oilseed cakes, rice bran) would rise from 24 to 58 million tons (expressed in cake equivalents). The latter would make up 42 percent of China's protein feed consumption.

rights and their marketability proceed; voluntary exchange platforms can also help.

The trend in land rental, from 7 percent of agricultural land in 2000, to 19 percent in 2008, is strongly positive. In the more developed eastern provinces such as Zhejiang, it even reaches as high as 40%. There are also reports of complete village reorganizations into large, company run farms whereby remaining villagers give up their land in return for housing (and lifetime compensation) at the urban fringe. The scale of such consolidation initiatives is so far unknown, as are the longer run welfare consequences. Overall, lingering concerns about tenure security and substantial coordination costs continue to hamper consolidation. These costs are even higher in mountainous areas, where plots are even smaller and more scattered. Recent evidence underscores the singularity with which land certification can increase productivity (by up to 30 percent), not so much through increased investment, but rather by fostering urban migration and freeing up land for rental by those specializing in farming.

Enhancing rural social protection will also help free up land for renting, as will the removal of remaining barriers to labor mobility.

When the latter is accompanied with small and medium town development, part time farming could also be promoted, especially in mountainous areas where opportunities for land consolidation are more limited. Such a strategy can build on the “leaving the village without leaving the country side” policy of the early 1990s, which proved successful in generating rural nonfarm employment nearby through the development of small towns in coastal areas. The conditions are much more favorable now to absorb the next wave of urban migrants by developing small and medium towns also in China’s interior provinces, as labor intensive industries are moving inland, following rapidly rising labor costs along the coast. It

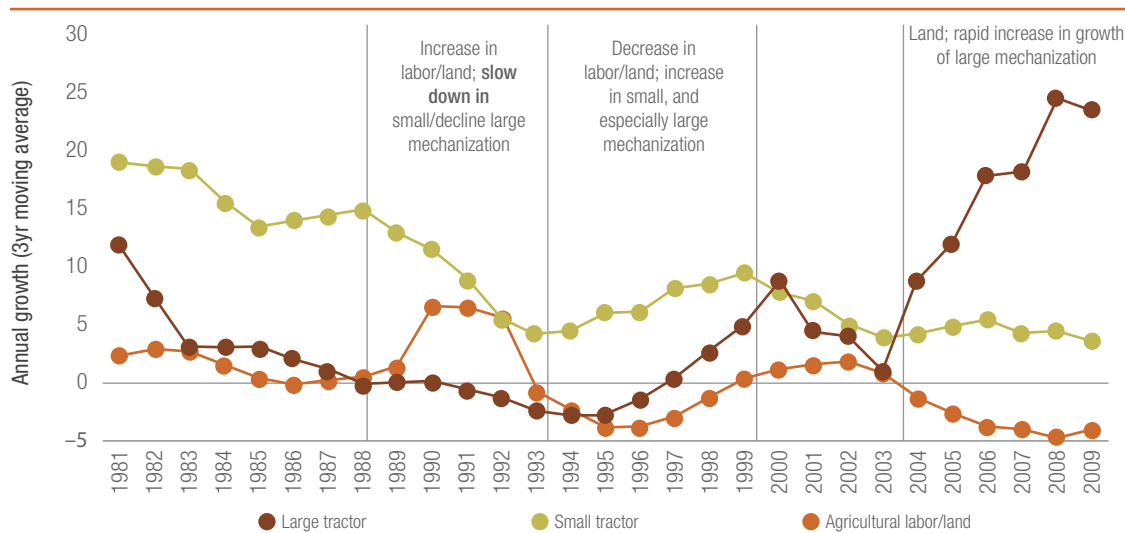
requires increased investment in rural education, improved rural transportation to link towns with their rural hinterlands and farmers with their off-farm jobs in rural towns, often in related agro industries. Consistent with the gradual reform approach, the next reform phase of the hukou system should focus on facilitating migration to these small and medium towns.

Finally, machine rental markets can go a long way in helping smallholders capture the economies of scale from mechanization necessary to overcome rising labor costs. While remittances and informal credit largely sufficed to finance modern inputs in the past, mechanization of (especially) grain cultivation will require greater access to bank capital in rural areas. But credit market imperfections can also be mitigated through institutional innovations such as machine rentals. The use of machine renting has historically been practiced in many Asian (and other developed) countries to capture economies of scale and is also on the rise in China. If properly coordinated, machine rentals provide a practical and convenient way to substitute capital for labor and overcome the indivisibility of machine inputs when credit markets are absent or imperfect. They also facilitate part time farming, which is often most in need of labor saving technology. The government has rightly been supporting the development of such machine service delivery organizations, though credit for leasing might be more optimal than direct subsidization of machinery. The pressure to mechanize underscores the need to reform the rural finance sector, with the government focused on creating the infrastructure and market environment for rural finance instead of direct public provision of financial services.

Farmer cooperatives enable smallholders to capture the economies of scale in the processing and marketing of high

FIGURE D

GROWTH IN AGRICULTURAL MECHANIZATION ACCELERATES WHEN THE AGRICULTURAL LABOR/LAND DECLINES, AS SINCE THE EARLY 2000s; IT DECELERATES WHEN THE AGRICULTURAL LABOR/LAND RATIO INCREASES



Source: China Statistical Yearbook, 2010.

value agricultural products, if implemented properly. They help smallholders reduce transaction costs in ensuring volume, consistency and quality and are a potent vehicle to link them to the high value markets. Tightened control over the production process also increases food safety, and the concentration of animals in larger production units facilitates animal waste management (e.g. through biogas digesters), mitigating agriculture's field problem. Since the enactment of the China Farmers Professional Co-operative Law (FPCL) in 2007, there has been a rapid expansion of farmers' cooperatives. But there are rising concerns that the emerging cooperative structures do not enable smallholders to capture the full benefits from high value products. They appear often dominated by a company or a few larger farmers, who retain the decision power and appropriate most of the profits. Cooperatives need to be monitored and steps taken in order to better protect the interests of minority shareholders, and to maximize their potential in addressing agriculture's farm problem.

3. CONTINUE TO STRENGTHEN THE PROVISION OF (RURAL) PUBLIC GOODS

Continue to increase investments in agricultural R&D and extension to retain smallholder grain competitiveness and foster the adoption of sustainable agronomic practices. Given constraints on expanding land, water and modern input use and institutional limits on the speed of land consolidation, growth in total factor productivity (TFP) will be key to keep smallholder farmers competitive. Despite massive investment over the past decade, investments in agricultural R&D will still have to increase by 15% annually between 2005 and 2020 to maintain the 1995–2005 yield growth. China is increasingly betting on agricultural biotechnology, focused on crops for the domestic market in which it misses a natural comparative advantage. GM rice and maize are nearest commercialization. But, how broader awareness about GM crops will affect consumer acceptance is an important development to be

watched. GM maize, widely adopted in the US and Latin America, may face less resistance as animal feed. Research and demonstration of sustainable agronomic practices offer great promise. For example, nitrogen consumption in some areas could be reduced by 30 percent without loss of output. Achieving this fertilizer use reduction will require, however, extensive extension and a possible reversal to larger institutional funding of extension agents.

In addition to agricultural R&D, increasing investment in rural education and rural roads has also high payoffs in mitigating both the food and farm problems. Notably, the marginal returns to low grade roads (most of which are rural) are estimated to be higher than those to high grade roads. The returns are highest in lagging regions, consistent with the regional shift in investments under the 10th and 11th five-year plans, with the decline in overall inequality hinting at some success. Following the relocation of businesses inland as labor costs rise rapidly along the coast, many rural off-farm opportunities are likely to open up, increasing the returns to rural roads and small town development in interior China. In this, the potential of nurturing cluster development deserves special attention, in analogy with their previous success in coastal areas. The returns to rural education were also high, but high costs cause rural children (especially in poorer communities) to drop out early from secondary schools and reduce their participation in college. This can be addressed through conditional cash transfers and experimental reforms of intergovernmental fiscal systems and the inclusion of social development targets in the performance evaluations of local cadres.

Tackle food safety issues more effectively. Despite enormous efforts, frequent food safety scandals continue to damage public

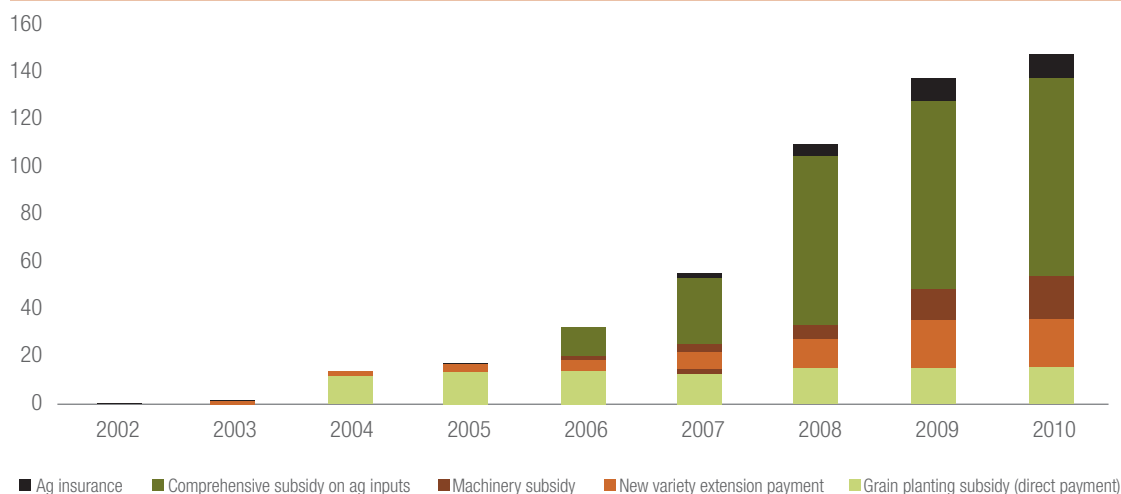
health and undermine consumer confidence in Chinese agricultural produce, at home and abroad, preventing China's agriculture to fully benefit from the employment and income generating opportunities that the rising domestic and international demand for high value products presents. While food safety problems are not unique to China, they must be addressed more forcefully. This will require greater awareness, an upgrading of the legal frameworks and regulations to cover the whole food chain, a clarification and consolidation of responsibilities by government agencies including a separation of risk assessment and management, and a focus of the government on responsibilities that are inherently public—such as the enforcement of rules and regulations through risk based monitoring and testing. The government should also assist and induce the food industry to take up their proper responsibility. To implement this agenda the capacity of both the public and private sector will further need to be strengthened.

4. SUPPORT RURAL INCOMES WHILE AVOIDING THE SUBSIDY TRAP

Producer support in China has risen rapidly from being negligible ten years ago to 17 percent of gross farm receipts in 2010. In addition to distortionary measures, WTO-permitted subsidies/transfers increased from about RMB 100 million in 2002 to about RMB 147 billion (US\$21.5 billion) in 2010. Input subsidies (rising seven-fold between 2006 and 2010) make up the bulk (Figure E). One way forward to meet WTO commitments while continuing to support farmers and address agriculture's field problem, is to eliminate agro-chemical subsidies and use income support mechanism instead. Unconditional income support programs, decoupled from production, have been successfully applied in Mexico. But, conditions

FIGURE E

AGRICULTURAL SUBSIDIES (BILLION YUAN) IN CHINA HAVE RISEN EXPONENTIALLY OVER THE PAST DECADE (2002–2010)



Sources: OECD 2009, 2011; Lei Meng, 2010.

could be usefully added. Farmers' incomes could for example be supplemented when they adopt more sustainable and less nitrogen rich land management practices. Future support streams could also serve as collateral to relax credit constraints (Pro-Campo, Mexico). This requires public registries that formalize property rights, such as to land and water.

5. IMPROVE AGRICULTURAL WATER AND ANIMAL WASTE MANAGEMENT

The institution of water fees that reflect actual costs, including pollution discharge, and water user rights and water trading can help allocate agricultural water more effectively and reduce its use. With remote sensing and geographic information systems, managing water use based on actual consumption is now more possible. Implementation requires well functioning water users associations and strong river basin authorities including all stakeholders to help resolve inevitable conflicts. To reduce nutrient leaching to

ground and surface water from the increasing concentration of intensified livestock production in (peri-)urban areas proper animal waste management practices and regulations (including zoning) will be needed. This will also reduce the atmospheric emissions of excess nitrogen and the increased risk of animal and human pandemics, such as avian flu.

6. MANAGE RISKS BETTER—ADAPT TO AND MITIGATE THE EFFECTS OF CLIMATE CHANGE

Adaptation to climate change in agriculture will involve expanding trade, technology and better short term risk management based on refined agro-weather and climate information. The increased focus in R&D on drought, heat and flood resistant varieties of the major crops should continue. Improved agro-climatic information for farmers can further improve climate resilience of agriculture. Weather-indexed insurance schemes hold promise to manage risks. But agriculture is also an important sector for achieving

the national target of reducing carbon intensity by 40–45% by 2020—the mitigation agenda. It contributes the most green-house gases after power. Reforms in both the livestock and crop sector can help. In addition

to better animal waste management practices, mid-season drainage can, for example, be an effective option to mitigate the carbon-footprint of rice fields, especially when N fertilizer application rates are reduced.

INTRODUCTION

China is an agricultural growth and poverty reduction success story. Ever since China embarked on its reform agenda more than 30 years ago, its economic growth and poverty reduction have been nothing less than remarkable. Agriculture has been an important contributor to these developments.³ Since 1978, China has almost doubled its cereal production (rice, wheat and maize)⁴ and it is now feeding 1.3 billion people, or 20 percent of the world's population, while having less than 11 percent of the world's agricultural land and less than 6 percent of its water.⁵ By providing abundant and cheap food, agriculture kept nominal wages low and paved the way for China's export led industrialization and its ensuing growth miracle. At the same time, by raising farm incomes, agriculture has also been the driving force behind China's massive reduction in (absolute) poverty, herein aided by the equal distribution of the user rights of its farm land.⁶

But new challenges are presenting themselves for China's agriculture, and old ones are resurfacing. High (land saving) TFP growth and increasingly open domestic and international markets, combined with grain self-sufficiency targets, a multitude of very small, fragmented production structures, and distorted land and labor markets have defined Chinese agriculture over the past three decades. Defying the predictions of many,⁷ they have enabled China to secure an ample supply of cheap grains, provide its farmers with much better incomes and largely free its population from hunger. But, as income growth in its (urban) non-agricultural sectors roared ahead and agriculture's exploitation of its land and water resources continued unabated, a series of new challenges have emerged, while old ones are resurfacing.

Agriculture's farm (income) problem. First, and foremost, farmers' income growth is ever struggling to keep up with non-farm income growth, undermining social and political

³ World Bank (2007); Ravallion (2009).

⁴ Cereal production increased from 247 million metric ton (mmt) in 1978 to 474 mmt in 2009.

⁵ World Bank World Development Indicators consulted on June 2, 2011. Agricultural land concerns land that is under temporary and permanent crops or pastures, land under market or kitchen gardens, and land temporarily in fallow. The water flows considered here, refer to internal renewable water resources present within countries, i.e. the internal river flows and groundwater from rainfall.

⁶ Ravallion and Chen (2007); Montalvo and Ravallion (2010); Christiaensen, Demery, and Kuhl (2011).

⁷ Lester Brown (1995; 2011) has just been one of the more notable and vocal proponents that China will be unable to feed its population.

harmony. How to address this growing rural-urban divide poses a major challenge. Similar pressures on agriculture and its smallholder farms have historically been observed during the structural transformation in most developed western and Asian countries. It is commonly referred to as agriculture's "farm (income) problem"⁸ and has in the past often resulted in the adoption of politically expedient, but economically inefficient agricultural subsidies and protection.


The "farm (income) problem" is particularly pertinent in China today. Now that not only urban wages, but also rural wages are starting to rise rapidly, it is becoming increasingly hard for China's smallholder and fragmented farms to generate incomes and income growth commensurate with what could be earned off the farm by farming only. Farm consolidation provides an answer, but inertia is bound to be substantial given tenure insecurity and the extensive transaction costs involved in exchanging the multitude of tiny, fragmented plots, even if factor markets were completely undistorted. Which agrarian structure to promote (smaller versus large farms) to keep staple food supply up and cheap (food problem), while taking maximal advantage of agriculture to generate remunerative employment and bring the rural-urban divide down (farm (income) problem), is undoubtedly one of China's prime conundrums moving forward.

The field problem. Second, soil erosion, especially in the western provinces, depletion of the water tables in the northern plains, and nutrient leakage from over fertilization in China's more densely populated grain producing areas are eroding its natural resource base. Mounting animal waste from intensifying animal husbandry that is increasingly

concentrated in (peri) urban areas to meet rising demand for meat is bound to further aggravate agriculture's environmental pressures. These developments and trends come in the face of increasing urban competition for China's agriculture resource base (water and land) and declining tolerance for agriculture's abuse thereof. This describes agriculture's emerging "field problem". It also highlights the limits of China's current agricultural model of intensification based on copious use of water and chemical inputs to meet future cereal demand. The increasing concentration of its animal production next to its consumers further poses important human health hazards.

The re-emerging food problem. Over the past 15 years, agricultural policies have gradually shifted away from a focus on securing aggregate food supply to improving individual access to food among the increasingly few that continue to struggle with hunger. But, two bouts of double-digit food price inflation over the past three years suggest that aggregate food supply is struggling again to keep up with rapidly rising demand, hinting at a resurgence of the "food problem". In particular, as labor costs rise and international imports of grain become more competitive following Renminbi appreciation, while changes in the agro-climatic conditions add uncertainty, it is becoming increasingly taxing to secure all cereal supplies (rice, wheat, and maize) through self sufficiency, especially since these more recent developments are compounding longer standing challenges posed by China's land constraints and growing water scarcity. Greater reliance on cereal trade provides an alternative. But, it may face political resistance, especially if it were to undermine China's food sovereignty. It may also perturb the international markets, especially

⁸ The terminology of 'food' and 'farm problem' to describe the quite different challenges agriculture faces in lower and higher income countries goes as far back as Schultz (1953).



if the policy shift is sudden and substantial. How to secure sufficient cereal supplies in the aggregate has started to re-occupy China's agricultural policy agenda.

But, as supply constraints tighten, demand dynamics also provide opportunities, as do agronomic practices to produce more with less. As China grows richer and urbanizes, its diets become more protein rich (meat and dairy) and diversified (fruits and vegetables).⁹ Producing these high value products is more labor and less land and water intensive. This opens up important new business opportunities for agriculture to help overcome its “farm (income) problem”. Second, the dietary shift also comes along with a slowing growth in the demand for staple cereals. This reduces some of the pressure on agriculture’s “food problem” as well as its “field problem”. It is the demand for animal feed (maize and soybeans) that will drive future cereal demand. While this demand will be substantial, cereal feed is a less laden commodity. It also has more substitutes (e.g. cassava, potatoes), rendering reliance on trade politically more palatable. Finally, important agronomic opportunities have been identified to reduce agriculture’s environmental footprint and tackle agriculture’s “field problem”. Extensive research from China’s fields suggest for example that crop nitrogen use could be reduced by at least 30 percent while maintaining yields through the application of different agronomic practices. Yet, not all environmentally friendly practices will generate immediate cost savings and important intertemporal trade-offs will need to be made.

Success of China’s agriculture is critical for China, and the world. Clearly, how to modernize China’s agriculture so as to fully

exploit its potential to contribute to reducing the rural-urban divide (the farm problem), while maintaining its ability to secure affordable food for all (the food problem) and safeguarding its resource base for the future (the field problem) poses a major challenge. Robust and broad based growth in agriculture provided the backbone for its take-off in 1978. How China will shape its agriculture in addressing these new (and re-emerging) challenges—the farm and field and food problems—will be equally consequential in determining its success in reaching its ambition of becoming a modern, harmonious and high income society by 2030. A modern, updated vision for China’s agriculture 2030 and a path stipulating how to get there are needed. As the world’s largest agricultural economy and a leading importer and exporter of agricultural products, this is not only important for China itself. Ripples in China’s domestic agricultural markets will reverberate like waves internationally, especially when shifts are unanticipated and/or abrupt. Both China and the world stand to benefit from a more profound understanding of the challenges and opportunities China’s agriculture faces and the policy responses it anticipates.

The report’s road map. The report proceeds by proposing a vision for China’s agriculture 2030 in section 2, a vision which is embedded in its historical context and draws on the empirical and theoretical insights about the role of agriculture as countries develop. The structural features of China’s agriculture today and the emerging challenges in fulfilling its three functions tomorrow are then analyzed in detail in section three. This sets the stage for delineating core areas for policy dialogue and intervention in section four, punctuated with some concrete suggestions.

⁹ Meat consumption per capita is projected to increase to 73 kg per person per year in 2030 for example (up from 53 kg in 2010 and 25 kg in 1990).

TOWARDS A VISION FOR CHINA'S AGRICULTURE 2030

Ingredients for a Vision. Generating decent and intersectoral comparable livelihoods for its farmers, sustainably managing the natural resource base, and securing access to food for all are agriculture's three quintessential functions. Meeting these three objectives often entails trade-offs, between efficiency, equity and sustainability. Formulating a vision for a country's agriculture thus requires determining the relative importance of each of these objectives. This often translates in specifying where on the range between full food self sufficiency and fully market mediated food security the country would like to position itself in securing its food supply. Given different social implications, it further necessitates a stance on the agrarian structure the country seeks to promote to do so—including a mixture of small to medium sized commercial family farming system (including part time farming) and larger scale corporate farming structures. To motivate the vision and given deep path dependency in policy making, this chapter begins by a brief review of where China's agricultural policies are today in relation to these three functions as well as how they got there.

Agriculture in China 1978–2000 focused on food, with the farm income problem emerging. From the late 1970s until the 2000s, the emphasis of the Rural Reforms in China was firmly, and successfully, on resolving the food problem. It resulted in an abundant supply¹⁰ of inexpensive food¹¹ and enabled China to largely resolve (though not eliminate) its hunger problem and dramatically reduce poverty.¹² Between 1980 and 2000, average rural per

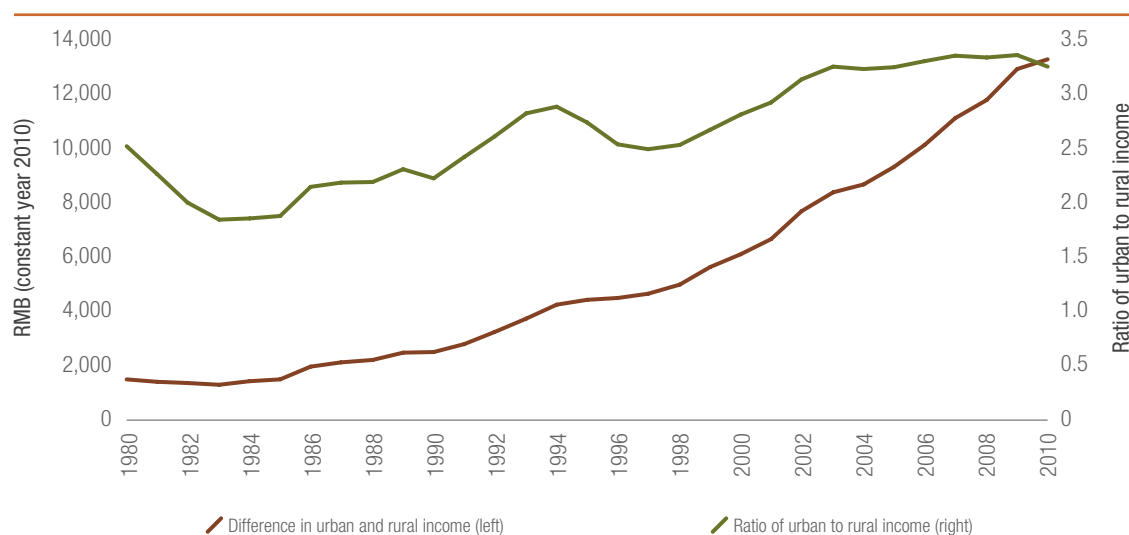
¹⁰ Grain output per capita rose from 319 kg/capita in 1978 to 393 kg/capita in 1990. It declined to 334 kg/capita in 2003 (following a large release of grain stocks during the early 2000s) to rise again to 399 kg in 2009. Furthermore, following dietary shifts, especially since the 1990s, meat production (pork, beef and mutton) quintupled between 1978 and 2009, from 9 to 44 kg/capita, milk production rose from 1.2 to 26 kg/capita and aquatic production rose from 4.9 to 38.4 kg/capita.

¹¹ Grain prices fell in real terms by 33 percent (maize) and 45 percent (wheat) between the late 1970s and early 2000s. Coupled with rising incomes, falling grain prices reduced the budget share for grains in consumption from nearly 40 percent in the 1970s to about 14 percent for rural households in 2004. In urban areas, the grain budget share dropped from 20 to less than 3 percent in 2003.

¹² Between 1981 and 2001, the fraction of the population below 888 Yuan per person per year at 2003 rural prices (World Bank poverty standard) fell from 65 percent (comparable to India's poverty rate at the time) to 33 percent in 1990, cut by half again by 2001 to 15 percent and 10 percent in 2004. The absolute number of poor fell from 652 million to 135 million, a decline of over a half a billion people (World Bank, 2009). Using the latest official poverty line of 2,300 Yuan/year per rural resident, which is slightly less than \$1-day, 128 million people were poor in 2010.

FIGURE 1

THE DIVERGENCE BETWEEN AVERAGE URBAN AND RURAL INCOME CONTINUES ITS EXPONENTIAL RISE



Source: NBS (2010 and 2011).

capita incomes tripled from 719 to 2253 (in real 2000 Yuan). Yet, urban incomes rose even faster.¹³ As a result, after the initial decline in the rural-urban income gap between 1978 and 1984, when agriculture was especially buoyant, the ratio of average urban to average rural income increased from 2.1 in 1985 to 3.5 in 2009 (Figure 1). The growing media attention to the rural income problem was about ratios, not levels.

Rising discontent among China's rural populations turned addressing this rural-urban imbalance into a major policy objective and resolving the "farm (income) problem"

became as important in the design of agricultural (investment and price) policies as ensuring an abundant supply of inexpensive food, the "food problem". These were further complemented with targeted poor area development programs to address persistent pockets of hunger and food insecurity¹⁴ in more remote and lagging counties and villages, many of which were in the western provinces.¹⁵

From 2000 onwards, the farm problem dominated, with field problems lurking in the background. Following the "take-less-and-give-more" principle, the longstanding net fiscal flows from rural to urban areas

¹³ The decline in the agricultural labor force (from 69 to 50 percent between 1980 and 2000) did not parallel the income growth rates in industry and services, which were even faster than in agriculture.

¹⁴ The availability of ample supplies at the national level usually goes along with a substantial decline in the incidence of hunger, but doesn't eliminate it. As Sen (1981) reminded the world, famines often happen, and pockets of food insecurity often persist, in the midst of plenty. As a result, the approach in addressing the food problem shifts as countries develop from a pre-occupation with securing national supplies to securing access to these supplies by all, including for those marginal groups and areas that continue to struggle with hunger and poverty despite sufficient aggregate supplies. This can be through raising their food producing capacity locally, often for those in remote areas where food markets are poorly integrated and food is thus not always available, or through raising their incomes, especially for those living in more integrated market areas.

¹⁵ This was part of the "Go West" strategy adopted in the 10th five year plan (2000–2005) and continued in the 11th five year plan (2005–2010).

to finance industrialization were reversed. Agricultural and rural fees and taxes were first abolished between 2003 and 2005, followed by an exponential increase in farm subsidies from a minuscule 100 million Yuan in 2002 to 55 billion Yuan in 2007 and 147 billion Yuan in 2010 (including a seven-fold increase in input subsidies).¹⁶ These developments in China's agricultural policies closely mirror those historically observed in other middle and high income countries.¹⁷ It has helped slow down the growth in the average urban to rural income ratio (reaching 3.53 in 2009). But, in absolute terms, the difference in income has continued to rise rapidly (reaching 10,504 (2000Yuan) in 2009).¹⁸ Though declining in number, pockets of food insecurity and hunger continued to exist, and were addressed by increasingly targeted interventions and expansion of social assistance.¹⁹ A beginning was further made in using agricultural and eco-compensation policies to address the "field problem", most notably through the "Grain-for-Green" subsidy initiated in 1999, which compensates farmers to retire marginal and sloping cropland.²⁰

Farm and resurfacing food problems will continue to feature prominently during the 2010–2030 period, with "field problems" increasingly capturing attention as China moves to 2030 as the population urbanizes and mindsets shift further. In the years ahead, the farm problem will undoubtedly take further prominence on China's agriculture agenda, as the rising rural-urban and interregional divides create serious political concerns (Box 1). And as discussed in section one, while "field problems" are increasingly capturing attention, food problems are resurfacing, posing trade-offs. The pertinent nature of such trade-offs is well illustrated by the recent shift in focus of the "Grain for Green" program from expansion into new areas to consolidation of ongoing conversions out of fear that the loss of land might jeopardize future food supplies. However, as the pressures on China's precious natural resources continue to build, including through intensification of livestock production in peri-urban areas, and urbanization further changes mindsets,

¹⁶ Subsidies include grain land based income transfers, grain land based input subsidies, new variety extension payments and agricultural machinery subsidies. The need for supporting agricultural incomes was explicitly mentioned as a motivation for the fundamental turnaround from taxing to subsidizing farmers (Central People's Government, China, 2008), in addition to continuing concerns about national food security. The latter arose from the decline in China's grain production following years of low prices and substantial destocking in the early 2000s as well as concerns about rising land pressure.

¹⁷ Hayami (2007). Figure 4.4, World Bank (2007).

¹⁸ The absolute and relative income differences reported here account for differences in the price evolution in rural and urban areas in China during 1978–2009, which were in effect minimal (Statistical Yearbook of China, 2010). However, they do not account for differences in cost of living between rural and urban areas in the base year (2000), and are thus likely to overstate the gap somewhat.

¹⁹ In the 2000s, China fine-tuned the targeting of its poor area programs from identifying nationally designated poor counties to nationally designated poor villages. It also started to increase direct transfers to its citizens for example through the rural dibao program. Nonetheless, in 2009, official statistics still put the number of people below 1196 Yuan/year (less than half the international poverty line of US\$1.25/day) at 36 million, or 3.8 percent of the population. At such low levels of income, people are still fundamentally food insecure, focused on solving their basic problems of hunger and clothing.

²⁰ A total budget of RMB 337 billion has been set aside for this Conversion of Cropland to Forests and Grassland Program (CFGP) (of which 130 billion has been spent during 2000–2006) enrolling 9.27 million ha of cropland and 13.67 million ha of wasteland (Bennett, 2009). Following its initial success, implementation has substantially slowed down since 2004 (OECD, 2011) given increasing (though largely unsubstantiated) fears that the program might jeopardize China's self sufficiency in grain production (Xu et al., 2006). The focus is now on operation and maintenance issues to consolidate and successfully complete the ongoing conversions as opposed to the conversion of new areas.

FOR DEVELOPMENT, THE NATURE OF INEQUALITY IS AS IMPORTANT AS ITS DEGREE

Rapid economic progress in China has been accompanied by rapidly rising inequality. This is strikingly illustrated by the rise in the Gini coefficient from less than 30 in the early 1980s at the start of the reforms, to 45 in 2005. However, the real threat of China's rising inequality lies in its composition, and not so much in its overall level. Inequality can be seen to arise from two sources: 1) inequality between groups and 2) inequality within groups. Inequality in the US, for example, is mainly driven by within group inequality, with rich and poor people in each state living side by side. In the enlarged European Union, on the other hand, the main cause of inequality lies in the difference in mean incomes between its member states, with the poor and the rich living geographically concentrated. And it is the large differences between poor and rich states within a country or within a political union such as the European Union, that tend to undermine political cohesion, especially when further grafted on ethnic, religious or cultural differences, and not so much the high levels of inequality as such.

This is a much less appreciated insight highlighted by Milanovic (2011) in "The Haves and the Have Nots – A Brief and Idiosyncratic History of Global Inequality". It is no accident, Milanovic contends, that at the time of the break up in 1991, the gap in GDP per capita in the Soviet Union, between its richest (Russia) and poorest (Tajikistan) republic was about 6 to 1, a gap similar to the difference in average income between South Korea and Ivory Coast. Inter-republican differences were even larger in the Former Yugoslavia. Slovenia was only four times as rich as Kosovo (in GDP per capita terms) in 1952, but grew to become 8 times richer at the time of its break away in 1991. This remains a very little talked about fact in the analyses of Yugoslavia's political breakdown. By way of comparison, in Italy, where regional inequalities are notoriously large, the richest state is about 3 times richer than the poorest one, while this ratio amounts to 1.5 to 1 in the United States or 1.4 to 1 in Germany.


With China's development shifting to the urban areas in the coastal provinces since the early 1990s, this top to bottom ratio increased from 7 to 1 in 1990 to reach 10 to 1 in 2006. Following the recent shift in policies to foster a harmonious socialist countryside and the massive amount of transfers and investments going to the rural areas, there are signs that the increase in the overall Gini coefficient may be leveling off (Fan, Kanbur, and Zhang 2011). In 2008, the Gini was actually even estimated at 42 (as opposed to 45 in 2005). Nonetheless, the economic cleavages among and within provinces, and between rural and urban constituencies, are clearly high and warrant continued attention, including for their implications for policy making in agriculture and rural development.

Source: Milanovic (2011).

environmental concerns will take on greater significance, forcing agriculture to increasingly evolve from an (ab)user of natural resources to a diligent custodian. This will also open up new opportunities to generate rural employment and simultaneously address the farm problem such as through eco-compensation programs. China's recent embrace of "green growth" strategies serves as a precursor of this shift in mindset.

This is the anticipated shift in relative emphasis on agriculture's three quintessential

functions as China charts its way to becoming a modern, harmonious, high income society. It builds on the ongoing changes in China's society and is consistent with the evolution historically observed in Japan, South Korea and several countries in Western Europe. However, in these countries, the transition has usually also come along with a reversal to subsidization and protection of agriculture to address the rising gap between farm and non-farm incomes. Even though politically expedient, it is economically and often also environmentally highly



inefficient. Following WTO accession, this path is somewhat curtailed in China's case, though the recent exponential rise in its support to agriculture serves as an eerie reminder of the profound challenge of avoiding the subsidy trap for agriculture when navigating a country's structural and occupational transformation. Against this background, the following vision for China's agriculture 2030 is advanced.

A vision for China's agriculture 2030.

China's agriculture in 2030 will predominantly consist of commercially viable small to medium sized family farms that ensure self sufficiency in strategic, but land and water intensive staple cereals such as rice and wheat, though not in maize. It maximizes rural employment opportunities in the production and processing of the labor intensive high value agricultural products (including meat and dairy) consistent with its natural comparative advantage, and it will act as a diligent custodian of its precious natural resources.

This overall vision serves as an overall guiding post, against which region specific interventions must be adapted in line with their endowment ratios.²¹ This vision of commercial smallholder farming and food self sufficiency ambitions (even though restricted) is cognizant of China's initial condition of small and fragmented farm structures as well as the political imperative of food sovereignty (not to be identified with food self sufficiency or food security). Commercial smallholder farming (and part time farming during the transition) will be argued to be economically viable, socially desirable, and politically sensible.

Realizing this vision for China's agriculture 2030 will be no small feat. Indeed, dietary change, rapidly evolving production cost structures and shifting ecological, agro-climatic and international environments are introducing new economies of scale, international competition and uncertainty that pose important challenges, especially to grain production and the current smallholder farm model. But, they bring also new opportunities.

²¹ Chen, Huffman and Rozelle (2009); Ito (2010).

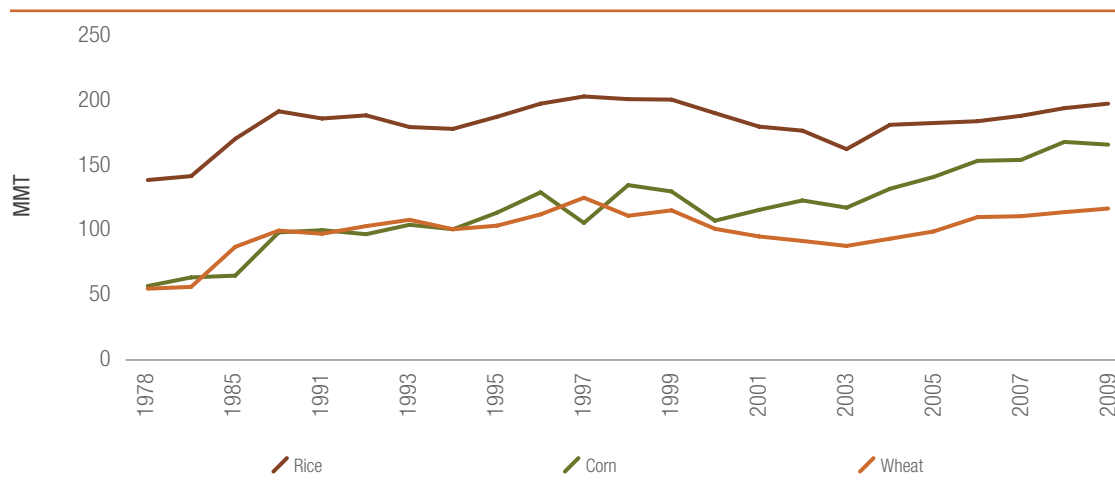
CHINA'S AGRICULTURE ANNO 2010 – CHALLENGES AND OPPORTUNITIES

3.1 THE STRUCTURE OF AGRICULTURE 1978–2010

Production structure – moving beyond grains, while keeping an eye on them. After China introduced its reforms in 1978, staple grain production expanded rapidly. Total cereal output (rice, wheat and maize) grew from 247 mmt in 1978 to 384 mmt in 1990, i.e. at an annual rate of 4.6 percent. It continued to expand thereafter, though at a slower rate. In 2009, cereal output stood at 474 mmt, with most of the increase since 1990 coming from maize.²² In particular, following satiation of demand for the key staples, rice and wheat, production peaked already in the late 1990s (Figure 2), while growth in the production of maize continued to feed the growing livestock sector.²³

FIGURE 2

RICE AND WHEAT PRODUCTION PEAKED AROUND 2000; MAIZE PRODUCTION RISING RAPIDLY SINCE



Source: NSBC, Statistical Yearbook of China, 2010.

²² Total maize output rose from 96.8 mmt in 1990 to 106 mmt in 2000, with its output growth accelerating rapidly thereafter to reach 163.9 mmt in 2009.

²³ Earlier in the reform period growth in maize production was pursued to maintain exports for hard currency.

Non-grain crop production (such as cotton and edible oils and vegetables and fruits) also increased rapidly during the initial reform period (Table 1). With the exception of cotton, non-grain crops continued their rapid pace of

expansion throughout the 1990s, with fruit production still growing by more than 20 percent a year well into the 2000s. Indeed the rise of the vegetable and fruit sectors has been so fast that it almost defies imagination. Between

TABLE 1

THE ANNUAL GROWTH RATES (%) OF AGRICULTURAL COMMODITIES, 1970–2010

Commodity	Pre-reform	Reform period				Post reform
	1970–78	1978–84	1985–95	1996–2000	2001–2005	2006–2009 ^a
Agricultural Gross Domestic Product	2.7	7.1	4.0	3.4	3.9	3.5
Grain total						
Production	2.8	4.7	1.7	0.03	1.1	2.3
Sown area	0.0	–1.1	–0.1	–0.14	–0.7	1.1
Yield	2.8	5.8	1.8	0.17	1.8	1.2
Rice						
Production	2.5	4.5	0.6	0.4	–0.8	2.0
Sown area	0.7	–0.6	–0.6	–0.5	–0.8	0.7
Yield	1.8	5.1	1.2	0.8	0.0	1.3
Wheat						
Production	7.0	8.3	1.9	–0.6	–0.4	4.3
Sown area	1.7	–0.0	0.1	–1.6	–3.1	1.6
Yield	5.2	8.3	1.8	1.0	2.7	2.7
Maize						
Production	7.4	3.7	4.7	–1.3	5.6	4.1
Sown area	3.1	–1.6	1.7	0.8	2.7	4.3
Yield	4.2	5.4	2.9	–0.9	2.9	–0.2
Total cash crop area	2.4	5.1	2.1	3.5	1.5	3.4
Cotton						
Production	–0.4	19.3	–0.3	–1.9	6.5	2.8
Sown area	–0.2	6.7	–0.3	–6.1	5.3	–0.5
Yield	–0.2	11.6	–0.0	4.3	1.2	3.3
Edible oil crops	2.1	14.9	4.4	5.6	0.8	0.6
Vegetable area	2.4	5.4	6.8	9.5	3.1	1.0
Fruit						
Orchards area	8.1	4.5	10.4	2.0	2.4	2.6
Outputs	6.6	7.2	12.7	10.2	21.0	6.1
Meat (pork/beef/poultry)	4.4	9.1	8.8	6.5	4.9	2.5
Milk	—	—	—	5.7	25.5	6.8
Fishery	5.0	7.9	13.7	10.2	3.6	3.7

Sources: Huang and Rozelle, 2011 and NSBC, 2010.

1990 and 2005 China as a nation added the equivalent of the vegetable production capacity of California (the world's most productive vegetable basket) every two years. When it comes to fruits, it dedicates now twice the share of its cultivable land to fruit orchards than the next closest major agricultural nation (including the US, the EU, Japan, India).²⁴

Agriculture thus transformed itself from a grain first sector to one that is also producing cash crops and horticultural products. In addition, with growth in the live-stock and fishery sector outpacing growth in the cropping sector (Table 2), China also moved away from a crop-first agriculture. Double digit growth in meat production (mostly pork and poultry) dominated growth in the livestock sector throughout the 1980s and 1990s, with dairy production booming since the 2000s, and aquaculture emerging as an important new subsector. In 2005, the livestock sector contributed already more than a third to agricultural GDP, while fishery accounted for 10 percent, up from 2 percent in 1980. Between 1980 and 2005, the share of crops in agriculture dropped from about three quarters of total output to about half.

But, grain production is staging a come-back. Over the past 5 years, grain production has picked up again, particularly the production of the staples, rice and wheat, which grew at 2 and 4.3 percent per year respectively during 2006–2009. After years of taking land out of rice and wheat production, rice and wheat areas have been growing again since 2003. Rice and wheat production levels are now almost back to their peaks of the late 1990s.²⁵ This reversal in rice and wheat production follows the turn-around in the long term staple prices, which bottomed out after China restructured its stockholdings in the early 2000s. The price reversal came along with the *accelerated* decline in cultivated land area between 1999 and 2004 following the Grain for Green land restoration program. Together they heightened concerns about China's ability to maintain the food self sufficiency targets. They refocused China's attention back on rice and wheat production.

More broadly, these evolutions on the domestic market are consistent with the trends in the world market. After having trended downward for more than three decades since the last world food crisis in 1972, world cereal prices also picked up again following the turn of the millennium. Over the past

TABLE 2
CHANGES IN STRUCTURE (%) OF CHINA'S AGRICULTURAL ECONOMY, 1970–2005

	1970	1980	1985	1990	1995	2000	2005
Share in agricultural output							
Crop	82	76	69	65	58	56	51
Livestock	14	18	22	26	30	30	35
Fishery	2	2	3	5	8	11	10
Forestry	2	4	5	4	3	4	4

Source: NSBC, Chinas' Statistical Yearbook, various issues and China Rural Statistical Yearbook, various issues from 1980 to 2007.

²⁴ Huang and Rozelle (2011).

²⁵ Nonetheless, sown areas of rice and wheat remain still well below their maxima ever attained (by 14 and 22 percent respectively). The area sown with maize also reached its maximum in 2009.

5 years, world rice prices have on average been 2.2 times their 2000–2005 average.²⁶ Higher and more volatile world cereal prices are considered the new reality in the short and medium term.²⁷ This also matters for China, bound by WTO regulations since it joined in 2001. While the latter have not yet constrained China's agricultural policy room of maneuver to protect its domestic markets from international price movements through protection and subsidization, they may well do so in the future (see further section 4.4).

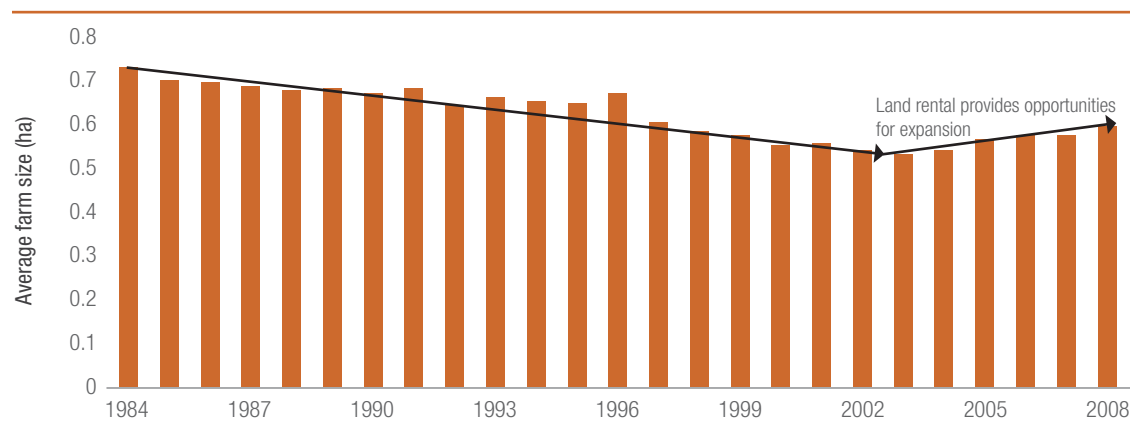
Farm structure—smallholder farming on small and dispersed parcels remains the defining form. China's agricultural

production has so far come almost entirely from small-scale operations, despite increasing competition following liberalization of domestic input and output markets and WTO accession in 2001. Strikingly, between 1980 and 2002 the average size of land controlled by farming households actually fell even further from 0.71 to 0.55 ha.²⁸ Average farm size has increased slightly recently, to 0.6 ha in 2008, through the renting of land (Figure 3). But, not only are farm holdings very small, they are further typically divided in several 4–6 separate noncontiguous parcels.²⁹

However, over the past few years, the number of producer and marketing cooperatives

FIGURE 3

SMALL FARMS GETTING SMALLER TILL 2002, WITH SOME CONSOLIDATION THROUGH RENTING THEREAFTER



Source: NSBC.

²⁶ They peaked in 2008, when they were up three times from their 2006 levels.

²⁷ Christiaensen (2011).

²⁸ This mainly followed from the continuing increase in the absolute number of people employed in agriculture and not from the decline in cultivated area, which, contrary to popular perception, actually increased slightly between 1986 and 2000 (see Box2). Between 1980 and 2002, the total population employed in the primary industry continuously rose from 291 million in 1980 to peak at 368 million in 2002. It has declined since to 297 million in 2009. This growth in the agricultural labor force till 2002 was driven by population growth and happened while the occupational transformation proceeded, with agriculture's share in total employment continuously declining, from 68.1 % in 1980 to 50% in 2000.

²⁹ These typically include one or two plots for grain, one plot close to the village for vegetable production, one plot on the more marginal hillside area, etc. This way both quantity and quality of land are equitably redistributed, as households get parcels in both more and less fertile areas (Lohmar, Gale, Tuan and Jansen, 2010). Tan, Heerink and Qu (2006) found these egalitarian principles in distributing and redistributing land following demographic changes to be the major force behind land fragmentation in contemporary China.

(called Farmer Professional Associations – FPAs) has risen rapidly over the past few years, and there are also an increasing number of anecdotes of companies cultivating large tracts of land. But, still relatively few villages and farmers belong to FPAs. According to Shen et al. (2005), as of 2005, only seven percent of villages had FPAs, of which only about one-third of the farmers belonged, resulting in a farmer membership of cooperatives of about 2 percent. This is far below almost all other East Asian nations and many Western nations during their development years, where participation rates were almost 100 percent. Following the adoption of the Farmers Professional Co-operative Law (FPCL) in 2007, there has been progress, with about twenty-two percent of villages having a cooperative by 2008 (Figure 4). About 13 percent of households belonged (5 percent are formal members and 7 percent are informal members) (Deng et al., 2010).

Clearly, while there is change, the organization of farm production is still predominantly on small farms run on fragmented plots,

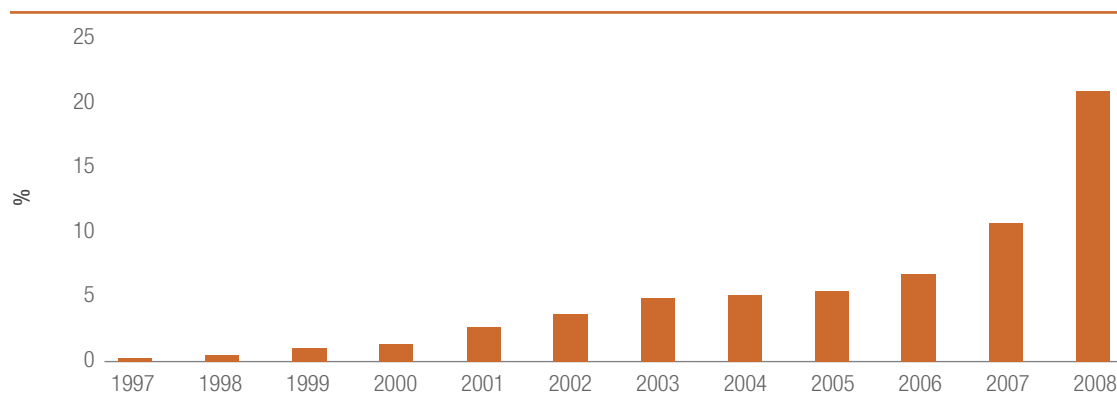
even though land consolidation and a thickening of the tails of the farm size distribution (more part time farming and larger commercial farm entities) are likely just around the corner.

3.2 DRIVERS OF SUCCESS

Total factor productivity growth through institutional change during 1978–1984 and land saving technologies thereafter have kept smallholders productive and competitive. Studies uniformly indicate that during the first years of reforms (1978–1984), TFP increased extremely fast, by 5 to 10 percent per year (Figure 5). This happened largely because of the introduction of the household responsibility system, which released an enormous amount of untapped potential.³⁰ Thereafter, TFP continued to rise at around 2 percent per year on average into the mid 2000s, including periods of lesser growth (late 1980s and late 1990s) and with TFP growth in the (richer) eastern and coastal regions consistently outperforming TFP growth in the other parts of

FIGURE 4

SHARE OF VILLAGES WITH FARMER PRODUCER COOPERATIVES INCREASED DRAMATICALLY SINCE ENACTMENT OF 2007 FARMERS PROFESSIONAL CO-OPERATIVE LAW (FPCL)

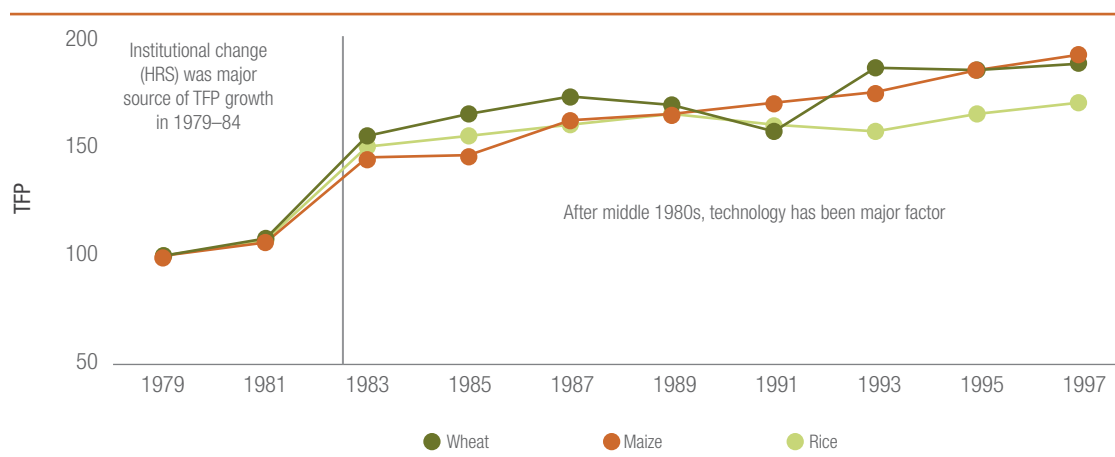


Source: Huang and Rozelle (2011).

³⁰ Fan, Zhang, and Zhang (2004).

FIGURE 5

INSTITUTIONAL CHANGE DROVE TFP GROWTH BETWEEN 1978–1984; TECHNOLOGICAL CHANGE THEREAFTER



Source: Jin et al. (2002).

China.³¹ Annual agricultural TFP growth of around 2 percent is substantial, also by international standards. For comparison, TFP in the US, many Western Europe countries and Australia grew by around 2 percent per year in the post WWII era.

Importantly, technological progress (shifting the production frontier outward) has been driving TFP growth since 1984, rather than improvements in efficiency (moving farmers up to the frontier). Producing on average at 80 percent of the production frontier, farming in China is generally quite efficient, though inefficiencies of scale have started to manifest themselves, suggesting less than optimal input-output positions.³² The TFP estimates further imply that technological progress has so far managed to outpace

productivity losses from soil degradation, at least during the 1990–2004 period.³³

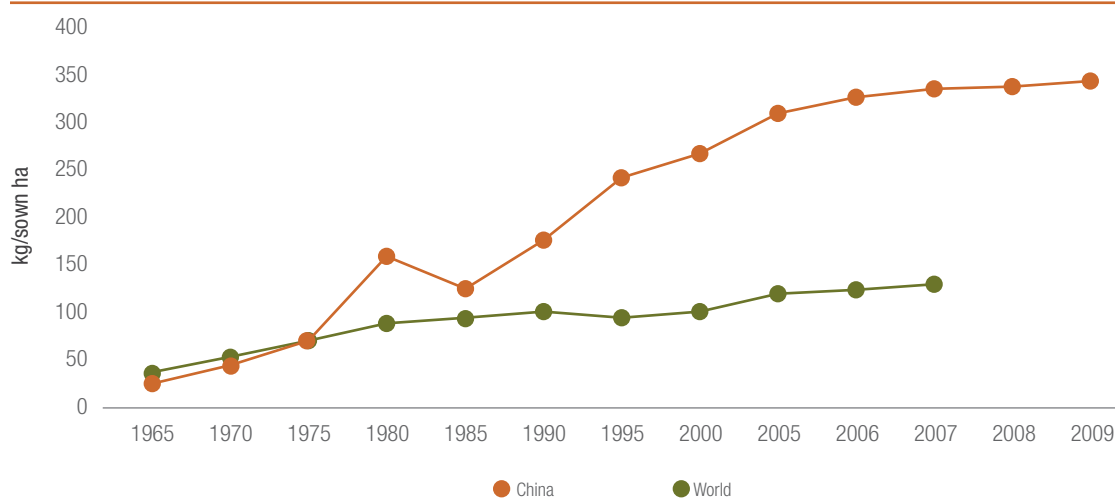
Among technologies, it is biological and biochemical technologies that have been shifting the frontier, and not mechanical or machinery technologies.³⁴ The former increase land productivity through the intensive use of intermediate inputs, the adoption of new varieties, and the improvement of soil and genetic resources, while the latter reduce the amount of labor needed—they are labor as opposed to land saving. At over 300 kg/ha in 2004 (three times the world's average), rising to almost 350 kg/ha in 2009, fertilizer use intensity in China is amongst the highest in the world (Figure 6). In provinces where land to labor ratios are much higher, or where rapid outmigration of agriculture

³¹ Fan (1997); Jin, Huang, Hu and Rozelle (2002); Chen, Yu, Chang, and Hsu (2008); Jin, Huang, Hu and Rozelle (2010); Ito (2010).

³² Chen, Yu, Chang, and Hsu (2008).

³³ Slower TFP growth in some of the lower income/western provinces was not due to lower technological progress—it actually exceeded 4 percent in Shanxi, Inner Mongolia, Anhui, Henan, Gansu, Qinghai, and Ningxia, but to a deterioration in technical efficiency. The latter may have been a consequence of localized soil degradation, but likely also reflects the steep learning curve associated with the rapid increase in machinery use in these provinces (Chen, Yu, Chang, and Hsu, 2008).

³⁴ Ito (2010).

FIGURE 6**FERTILIZER USE EXPANDED RAPIDLY TO AMONG THE HIGHEST IN THE WORLD**

Source: China Statistical Yearbook 2010 and World Development Indicators 2011.

dramatically increased the land to labor ratio as in Zhejiang and Jiangsu, more use is made of labor saving machinery. This foretells what is to come as agricultural labor markets are tightening across the country.

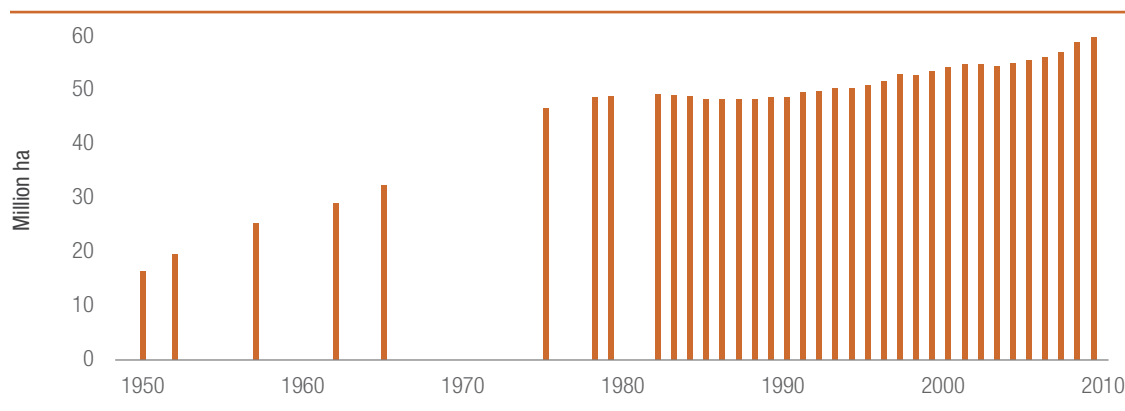
Yields were further boosted through expansion of irrigation, which, combined with the breeding of varieties with short growing cycles, enabled China to grow two to three crops per plot per year, in effect doubling to tripling the sown land area. Nearly 50 percent of China's cultivated land is now supported by irrigation facilities (Figure 7), with extensive irrigation being used in the more arid, northern parts of the country. In these parts, about 50 percent of the irrigation facilities are supplied with ground water, while irrigation in the rest of China relies mostly on surface water. In sum, intensive fertilizer use and irrigation, together with crop varieties especially developed by domestic research stations to thrive with abundant input and water use, have for a long time enabled China's smallholders to secure China's food supply and carve a living out of small farms.

Markets – liberalized input and output market fostered specialization. Early on in the reforms there were no concrete plans to liberalize markets. But beginning in the mid 1980s, and throughout the 1990s, China gradually liberalized its domestic output and input markets. However, important distortions persist in its factor markets (especially the land and labor markets). Markets for inputs are now largely free and lightly regulated. Seeds are supplied by thousands of small seed companies that often repackage seeds bought in bulk to be sold further under their own label in small input supply stores in villages and townships. This atomistic structure also characterizes the pesticide industry, rendering it equally difficult to regulate. Typically supplied by large companies, fertilizer is also distributed by a myriad of small scale, private traders.

While this has generated a competitive market structure, the lack of a regulatory environment to install and enforce quality standards has also led to the widespread sale of counterfeit, adulterated and poor quality farm chemicals, feeds and veterinary drugs,

FIGURE 7

IRRIGATED LAND TRIPLED BETWEEN 1950 AND 1978 TO 45 MILLION HA, INCREASING GRADUALLY TO 60 MILLION HA IN 2009



Source: China Statistical Yearbook 2010.

which at times pose important safety concerns.³⁵ The 1988 reforms of agricultural extension, which encouraged public agricultural extension system stations to earn their own incomes through commercial activities, further stimulated extension stations and agents to sell more chemical pesticides and fertilizers than needed, inducing overuse.³⁶

Unlike in the 1980s, when state-owned marketing bureaus monopolized agricultural marketing, small private traders, agri-businesses as well as local and State government-owned companies are now involved in grain marketing. Most horticultural and livestock products are marketed by a vast army of individual entrepreneurs trading on their own account. As a result, China's markets have become well integrated and efficient. Measured in terms of the percentage change in price

for every 1,000 km of distance from the port, which is between 4 and 7 percent, China's agricultural market performance is similar to that of the United States. Even farmers in remote, poor villages appear integrated into the national markets.³⁷ Market liberalization also facilitated specialization. The percentage of villages specializing in an agricultural commodity increased by 9 percentage points between 1995 and 2004,³⁸ especially where road access was better³⁹ and often taking advantage of the rising demand for horticulture and other specialty products.⁴⁰

International trade – agricultural production is increasingly consistent with China's natural comparative advantage. While the value of agricultural trade already grew by about 6 percent per year between 1980 and 2000, it more than doubled since WTO acces-

³⁵ Lohmar, Gale, Tuan and Jansen (2010).

³⁶ Huang, Qiao, Zhang and Rozelle (2001).

³⁷ Huang and Rozelle (2006).

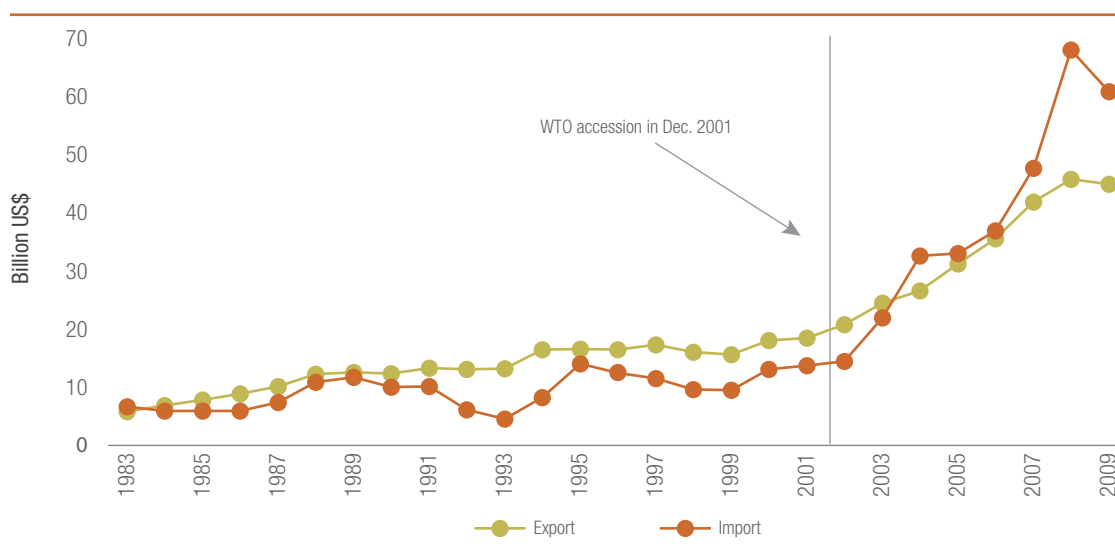
³⁸ Huang and Rozelle (2005).

³⁹ Qin and Zhang (2011).

⁴⁰ This is most vividly illustrated by the development of Anding from a low productivity wheat producing area into one of China's three leading potato clusters, with potatoes now accounting for 2/3 of the cropping area, producing 1 kg of potatoes for every Chinese and generating 60 % of rural people's income (Zhang and Hu, 2011).

FIGURE 8

CHINA EVOLVED FROM NET FOOD EXPORTER TO NET FOOD IMPORTER SINCE WTOACCESSION IN 2001



Source: International Trade by Commodity Statistics (ICTS) Database, 2011.

sion, rendering China now one of the world's top four agricultural import countries. Its imports jumped from under US\$11 billion in 2002 to over US\$57 billion in 2008.⁴¹ China's agricultural exports have also grown, although not as dramatically as imports, from US\$ 13 billion in 2002 to US\$39 billion in 2008. From being a small net agricultural exporter during most of the reform period, China thus quickly became a net importer after WTO accession (Figure 8).

More remarkably however, is the changing composition of trade that accompanied this shift. According to custom statistics, the net exports of land-and-water intensive bulk commodities, such as grains, oilseeds, and

sugar crops have fallen; exports of higher valued, more labor intensive products, such as horticultural and animal products (including aquaculture) have risen.⁴² China's trading pattern is aligning itself with its natural comparative advantage, which is in labor intensive crops and livestock products and not in land and water intensive grains.⁴³

Drivers of success in sum. Over the past three decades (1978–2009) China's agricultural sector has expanded and diversified substantially beyond grains. Its gross value of output (in constant prices) quadrupled and livestock and aquatic products contribute about two fifths of the gross value of output now, compared with less than one fifth in 1978. Crops

⁴¹ Lohmar, Gale, Tuan and Hansen (2010).

⁴² During much of the reform period, China exported maize and imported wheat, but imported only limited amounts of cotton and oilseeds. Today, China is largely self sufficient in rice and wheat, imports small amounts of maize, and large amounts of cotton (for its apparel industry) and soybeans (for livestock production, rising from 10 mmt in 2001 to more than 50 mmt during 2008–2010). At the same time, it evolved into a major exporter of many fruit, vegetable, and livestock products, including apples, garlic, aquaculture products, poultry and pork.

⁴³ Recall that while it has about 20 percent of the world's population, it has more than 35 percent of the world's agricultural labor force, but only 11 percent of the world's agricultural land, and less than 6 percent of its water resources.

account for about half the gross value of output now, compared to 80 percent at the beginning of the reform period. The production of this massive amount of agricultural output takes mostly place on fragmented plots on small smallholder farms, which until the mid 2000s were still declining in size. Land saving technological change (improved seeds, fertilizer use) coupled with the expansion of irrigation has been driving output growth, aided by liberalized input and output markets.

However, WTO accession in 2001 coupled with the gradual appreciation of the Renminbi (see further below) have increased competitive pressures, especially on grain production, with exports shifting away from the more land and water intensive cereals to the labor intensive horticultural and livestock products, and grain imports for animal feed (especially soybeans, but recently also maize) being on the rise. In addition, a number of developments in the factor markets and dietary shifts on the demand side are challenging China's current agrarian structure and policy environment to address its food, farm and field problems. These challenges are discussed in more detail below.

3.3 AGRICULTURE AT A CROSS-ROAD

3.3.1 Rising Supply Constraints

Agriculture's land base is under pressure, but maybe not as much as claimed. The

common (and most straightforward) way to expand agricultural production is to expand the land base. Once the (productive) land frontier is closed, the focus is on increasing yields, through water control (enabling multiple cropping) and the use of modern inputs. Nowadays, the scope for expanding the agricultural land base in China is limited. There is also rising competition for land for construction purposes (inhabitation, mining, infrastructure), which has contributed to the continuous decline of the cultivated land area from 130 million ha in 1997 to 121.7 in 2008 (Figure 9). Ongoing soil degradation compounds the decline in land, undermining its productive capacity, especially in the western parts of the country and where input use is limited.⁴⁴

The decline in the quality and quantity of China's agricultural land base have led the government to adopt the "Grain-for-Green" program in 1999 and to institute the so-called Red Line in 2006, respectively. Under the former program, sloped cropland is set aside to increase forest cover and prevent soil erosion, while the Red-Line institutes a dynamic balance quota of 120 million ha (1.8 billion mu⁴⁵) of land to be preserved for agricultural purposes.⁴⁶ Both policies have been contested, the first one for threatening China's self sufficiency goals in grain production by taking crop land out of production⁴⁷ and the second one for limiting the necessary conversion of land for economic growth⁴⁸ (Box 2). Irrespectively, the scope for increasing agricultural production

⁴⁴ Ye and Van Ranst (2009) estimate yield losses from soil degradation in the eastern, middle and western belts at $1 \pm 0.4\%$, $4 \pm 3.5\%$ and $25 \pm 3.1\%$ respectively.

⁴⁵ 15 mu of land = 1 hectare.

⁴⁶ During State Council 2008 Wen Jiabao emphasized that a minimum of 1.8 billion mu of basic farm land must be retained. It concerns in effect a "no net loss" policy requiring county and township governments to keep their good-quality cultivated land at the current level. If cultivated land is converted to other uses, an equal amount of other land, adjusted for the quality, must be converted to cultivation somewhere else, to compensate for the loss. As a result, cereal production is increasingly moving out of the more urbanized and industrialized coastal areas moving inland and to its outer provinces (Inner Mongolia, Heilongjiang and Xinjiang) where land reclamation has traditionally taken place.

⁴⁷ Ministry of Land and Resources (2004).

⁴⁸ Mao (2010).

FIGURE 9

CULTIVATED AREA DECLINED (1997–2009); SOWN AREA SLIGHTLY INCREASED THRU MULTIPLE CROPPING



Source: China Statistical Yearbook 2010.

through land expansion has clearly been exhausted.

The conversion of cultivated land has accelerated since, especially between 1999 and 2004. As illustrated in the table above, this was however not due to an acceleration of conversion for construction—the amount of agricultural land developed exceeded the amount taken out of production for built up.⁴⁹ Rather, it followed from the “Grain-for-Green” program, under which about 7 million ha of cultivated land was converted into forest land. The resulting loss in grain output was however minimal, as yields on the targeted slopes taken out of production were only 30 percent of the national average, and farmers increased their production efforts on the rest of their land, largely offsetting the declines from output loss due to reduction in area. The improved hydrological capacity of China’s mountainous areas may further increase productivity in the downstream regions.

These findings are not taken to show that there are no pressures on China’s grain producing capacity from continuing pressures on

its cultivated land base. Rather, they call for a comprehensive, national and data driven assessment of the situation, which also accounts for offsetting mechanisms, and promotes a rational management of the conversion process. They further underscore the importance of a continued focus on increasing the productivity of the remaining resources in the agricultural sector, as the scope for increasing agricultural production through land expansion is clearly non-existent.

Water pressures are real, though better water management also opens up opportunities. One avenue to relieve land pressures is multiple cropping through better water management. Over the past decade, China’s sown area has continued to hover around 155 million ha, rising to 158.6 million ha in 2009, despite a decline in cultivated area by over 8 million ha to 121.7 million ha in 2008 (Figure 9). As a result, the multiple crop index rose from 1.18 in 1997 to 1.3 in 2009. Yet, rising competition for water from industry and human consumption and declining water availability (from 2194 cubic meter/person in 2000 to 1816 cubic meter

⁴⁹ Chau and Zhang (2010).

CULTIVATED LAND LOSS IN CHINA – WHAT DO THE NUMBERS REALLY SAY?

The debate about agricultural land conversion hasn't always been well served by solid empirical evidence, with two carefully executed empirical studies suggesting that the actual loss in agricultural output potential due to land conversion for construction and ecological restoration may have been much less than often purported.^a In particular, between 1986 and 2000 the conversion of cultivated land to non-agricultural uses (mainly built up) has in effect been more than offset by the conversion from other land uses into cultivated land (especially grasslands in the north-western parts of China and the eastern parts of Inner Mongolia, forests in northeast China, and large tracts of unused wetland and barren land in Heilongjiang). This actually resulted in an estimated net *increase* of cultivated land of 1.9 percent. The newly cultivated tracts were however less productive than the converted cultivated land for construction (mostly along the east coast and around Beijing, Shanghai and Zhejiang). Nonetheless, overall, the resulting *net* decline in average potential productivity was only 0.3%. Source: Chau and Zhang, 2010.

TOTAL LAND DEVELOPMENT FOR AGRICULTURE EXCEEDS TOTAL LOSS DUE TO LAND CONVERSION FOR CULTIVATION

Year	Total addition		Total loss		Total area of cultivated land (year end)
	Total (Million ha)	Of which due to land development, consolidation and reclamation	Total (million ha)	Of which due to conversion to construction land	
1999	0.41	0.26	0.85	0.21	129.85
2000	0.61	0.29	1.57	0.16	128.88
2001	0.27	0.20	0.90	0.16	128.25
2002	0.34	0.26	2.04	0.20	126.56
2003	0.35	0.31	2.90	0.23	124.01
2004	0.53	0.35	1.49	0.29	123.06
2005	0.63	0.31	0.99	0.21	122.69
2006	0.72	0.37	1.03	0.26	122.38
1999–2006	3.82	2.35	11.76	1.73	

^a Xu et al., (2006); Deng, Huang, Rozelle and Uchida (2006).

per person now) limit the scope for expanding agricultural production through increased water use, rather the opposite.

In addition to being much lower than in the rest of the world, where water availability is on average above 7000 cubic meter per

person, water endowments in China are also unevenly distributed. They are relatively abundant in the south, but scarce in the north. Nonetheless, it is the north which is especially intensive in the production of water intensive crops such as soybeans, maize, wheat and cotton, including through irrigation.⁵⁰ And

⁵⁰ Most of the rice, which also heavily relies on irrigation, is produced in the relatively water-abundant southern parts of China. Most of the northern part of China receives sufficient rain for summer grain production during normal years. Winter wheat production on the other hand, relies heavily on irrigation. Overall, it is

through domestic food trade, northern China annually exports about 52 billion cubic meters of water in virtual form⁵¹ to the southern provinces.

This has resulted in severe groundwater depletion, with the deep water aquifer under the North China plain, for example, already dropping at about 3 m per year and about half of the communities using ground water in the northern plains reporting a decline in ground water levels between the mid 1990s and mid 2000s.⁵² Whether the water tables can be effectively and efficiently replenished through the south-north Water Transfer Project is debated. In effect, the current virtual north-south trade in water actually exceeds the maximum proposed water transfer volume along the three routes of the south-north Water Transfer Project.⁵³ These numbers would suggest that the regional distribution of cropping patterns may need to be revisited.

Nonetheless, systemic water scarcity in many regions has so far not prevented overall production from rising.⁵⁴ Scenarios suggest however that dietary shifts to animal products

(see below) together with population growth will further increase the crop water requirements for food production (1127 km³/year in 2003), by 36 to 46 percent by 2030, depending on the assumed speed in dietary change and the assumed reduction in the virtual water content of crops. This implies an additional amount of water needed ranging between 407 to 515 km³ per year, equivalent to 182 to 230 percent of consumptive irrigation water use in 2005.⁵⁵

But, China's low efficiency of current water use in irrigated agriculture also provides opportunities to improve its domestic food production capacity (the food problem) and remain internationally and intersectorally competitive (the farm problem) through better water management.⁵⁶ Yet, it is unlikely to suffice and increased virtual trade of water through increased import of more water intensive agricultural products such as grains may well have to be part of the answer. This will be discussed further below.

The scope for agricultural productivity gains through expansion of chemical input use is equally limited, but

estimated that 90 percent of rice production is irrigated, 85 percent of total wheat production, 45 percent of China's maize production and 30 percent of its soybean output (Fischer, Ermolieva and Sun, 2010).

⁵¹ The virtual water content of a crop corresponds to its total accumulated evapotranspiration over the complete growth cycle. It is generally higher for grains and most cash crops, and lower for potatoes, vegetables and most fruits (except citrus). If the amount of water lost through evapo-transpiration is not replenished, for example, with precipitation, crop water use will result in a localized net water loss and become unsustainable over time.

⁵² Lohmar and Hansen (2007); Wang, Huang and Yang (2009). While water availability is a pressing concern in the North China Plain (which includes the provinces of Henan, Hebei, Shandong and the northern parts of Jiangsu and Anhui), this is less of an issue in the Northeast (provinces of Heilongjiang, Jilin and Liaoning), where Fischer, Ermolieva and Sun (2010) still see scope for further expansion of irrigation.

⁵³ Ma et al. (2006).

⁵⁴ Lohmar, Gale, Tuan and Hansen (2010).

⁵⁵ Liu and Savenije (2008).

⁵⁶ During the mid 2000s, the amount of (irrigation) water used to produce 1 kg of grains (0.96 cubic meter or about 960 liter/kg of grain) was twice the amount used in developed countries (Zhao, Luo, Deng and Yan, 2008). Note that it concerns the application of irrigation water here, and not the crop water requirement as measured by evapo-transpiration during the crop's growth cycle. While more efficient irrigation practices would not change the latter, they help slow down depletion of the water tables, if water loss during the irrigation process on and off the farm, resulting in higher evaporation, is not replenished locally.

more output could be attained with less inputs, yielding important opportunities to save costs and reduce environmental pressure. At more than 300 kg per ha (340 kg/ha in 2009), China is already among the highest fertilizer users in the world (4th highest after Japan, Korea, and Holland in 2004) (Figure 6). The marginal productivity from additional fertilizer use was already declining rapidly in the 1990s (from an estimated 11.5 kg crops per additional kg of fertilizer in 1981–85 to 2.03 kg in 1991–95)⁵⁷ and may well have become negative since. Research undertaken under the UK-China Sustainable Agriculture Innovation Network (SAIN) suggests widespread 30–60% overuse of nitrogen fertilizer on crops. A report by the Ministry of Agriculture reported the efficiency of nutrient use was only 30–40%, compared with 60–70% in developed countries.⁵⁸

Low efficiency combined with over use of fertilizer has substantially contributed to nitrogen and phosphorus eutrophication of China's lakes and (ground) water systems. The manufacture and use of synthetic nitrogen fertilizer was estimated to produce 7 percent of China's total 2007 greenhouse gas emissions.⁵⁹ Deficiency of organic fertilizer use has further resulted in a decline in organic matter in soils, reducing soil fertility. China is also among the largest pesticides consumers in the world, much of it superfluous.

Clearly, increasing agricultural output by increasing chemical inputs is not an option. But, it may not even be necessary. Tests on thousands of farmer fields across China show

that fertilizer application rates could be cut in many situations, by at least 30%, through better agronomic practices, without loss of crop production or risk to the nation's aggregate food supply.⁶⁰ Similarly, the widespread adoption of transgenic insect resistant Bt cotton seeds has already substantially reduced production costs through a reduction in pesticide use by two thirds, increasing net income per ha by about 340 percent.⁶¹ This suggests that resolution of some of the field problems through smarter application of chemical inputs and GMOs can also provide important cost saving opportunities. This will also prove critical in resolving the food and farm (income) problem by keeping grain production competitive, domestically and internationally. This is especially relevant today in light of rapidly rising costs of agricultural labor.

Rising labor costs drive farm mechanization and farm polarization. Abundant agricultural labor has for the longest time been considered one of the defining features of China's agriculture. It has in the past inspired some observers to consider China as the ultimate example of a Lewis type economy, where (surplus) labor (with zero or low marginal productivity) could be extracted out of agriculture for employment in the non-agricultural sector (where wages are somewhat higher) without a reduction in overall agricultural output. A corollary to this view is that there were few incentives to substitute capital for labor in agriculture. This combined with relatively high labor to land ratios has made China's agriculture very labor intensive, with technological innovations focused on land saving technologies.

⁵⁷ Mao (2000).

⁵⁸ Zhao, Luo, Deng and Yan (2008).

⁵⁹ SAIN (2010).

⁶⁰ SAIN (2010).

⁶¹ World Bank (2007).

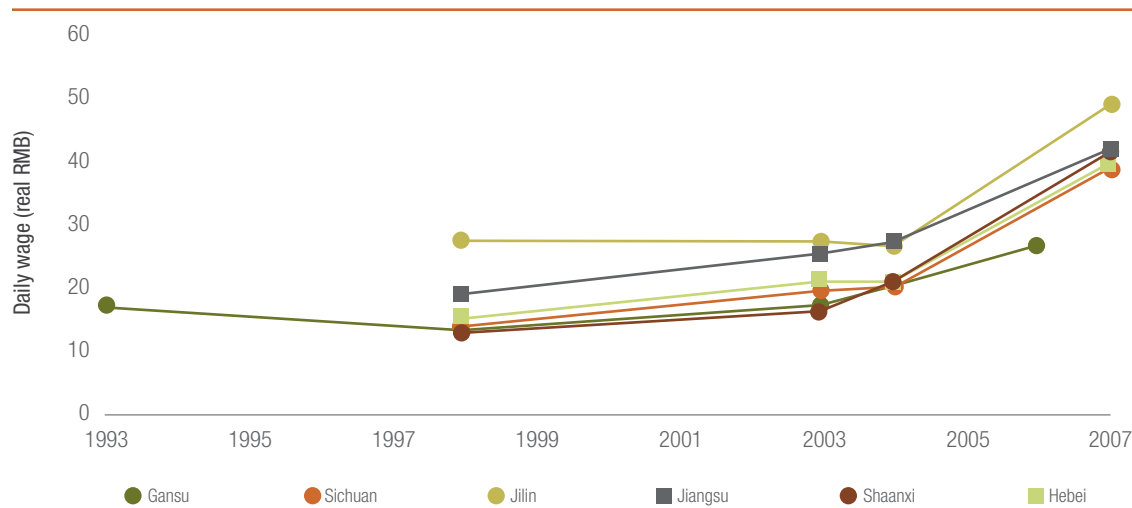
Looking ahead however, urbanization and the ageing of China's population are rapidly reducing the agricultural and rural labor force. About 20 million rural people are estimated to migrate to urban areas a year, while temporary migration is estimated at 100 million per year. These trends are already reflected in the average total hours spent per household on the farm, which declined from 3,500 hours in 1991 to just over 2,000 hours in 2000 and only 1,399 hours in 2009.⁶² Concentration of migration amongst the young further exacerbates the ageing of the rural demographic and with male migrants outnumbering females, agriculture in China is also feminizing.

Exhaustion of the demographic bonus and urbanization will push up the cost of rural

labor, including in agriculture. The observed acceleration in rural wages around the mid 2000s,⁶³ even in the more remote areas and provinces, such as in Gansu, suggests that these deep slow running demographic and economic forces have already started to bear themselves out in the labor markets (Figure 10). They are also reflected in the accelerated decline in the agricultural labor to land ratios observed since the early 2000s (Figure 11).⁶⁴

These developments have critical implications for the viability of the current farm structure and the resolution of the food and farm problem. Rising labor costs make capital, and thus mechanization of agriculture, more attractive, putting upward pressures on the farm size, given the economies of scale

FIGURE 10
RURAL DAILY WAGES HAVE RISEN SHARPLY SINCE 2003



Source: Zhang, Yang and Wang (2011).

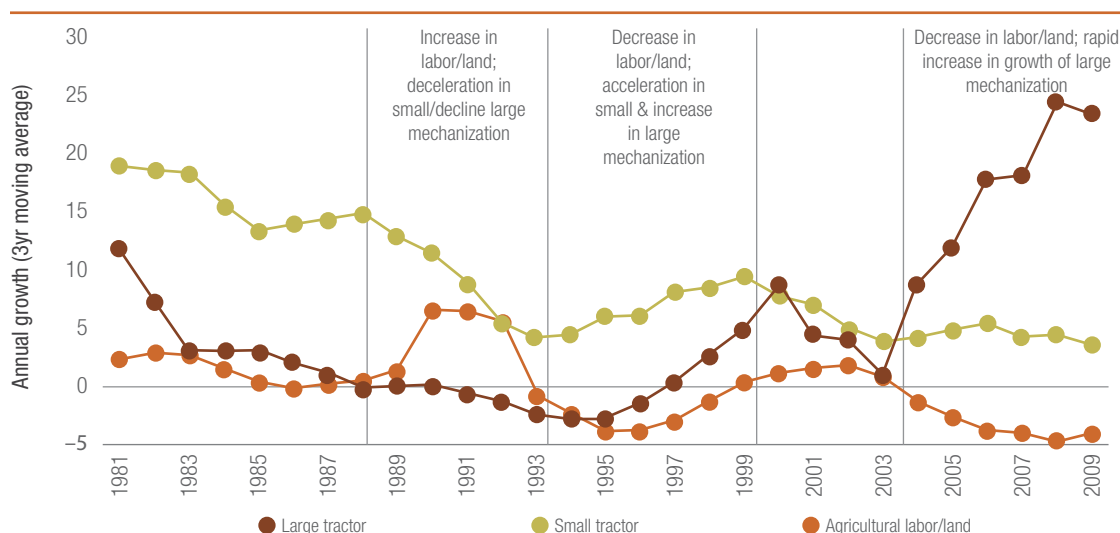
⁶² De Brauw, Huang, Zhang and Rozelle (2011).

⁶³ Zhang, Yang, and Wang (2011); Fleisher, Fearn, and Zhen (2011).

⁶⁴ Despite fears to the contrary, the feminization of agriculture has so far not been found to reduce efficiency in agriculture (De Brauw, Huang, Zhang and Rozelle, 2011). This has been attributed to the equal access by women to land, inputs and machinery services. The latter are particularly helpful as they enable women to also perform the heavier tasks and capture the economies of scale from machinery without needing the capital to invest in it themselves.

FIGURE 11

MECHANIZATION ACCELERATES AS AGRICULTURAL LABOR/LAND RATIO DECLINES (NEGATIVE GROWTH)



Source: China Statistical Yearbook 2010.

that come with the indivisibility of machinery.⁶⁵ These pressures are already manifesting themselves, with the accelerated decline in the agricultural labor-land ratio inducing a rapid acceleration in the growth of large and medium size tractor use (Figure 11), a trend which is lately also actively supported by the government through machinery subsidies.⁶⁶

Yet, these are early days and enormous challenges of adjustment lie ahead. Aggregating land through land rental and sales to obtain more commercially viable farming entities entails significant coordination costs. These

costs only rise when the available plots for rent are small, scattered, and usually not contiguous to one's own plots. Moreover, while machinery services can help smallholders capture the economies of scale from mechanization and remain internationally competitive, farm size expansion is also necessary to remain intersectorally competitive, i.e. to be able to generate enough income from the farm relative to what could be earned outside agriculture (Box 3). This poses a particular challenge in mountainous areas, where smaller plots on more sloped land make mechanization and land consolidation even harder.

⁶⁵ Another indivisible factor is a farmer's ability to acquire and process information. This becomes more important as agricultural technologies advance giving operators with formal schooling and technical education a competitive edge. It is most pronounced for those engaged in high value agricultural products characterized by increasing quality demands and tightening safety standards and will also gain in importance as the pressures to adapt to a changing climate increase.

⁶⁶ The sequencing of the argument is critical here (Kislev and Peterson, 1982; Hayami and Kawagoe, 1989). Mechanization as such is not driving the decrease in labor/land ratios here, but rather intersectoral labor market dynamics, whereby agricultural laborers are pulled out of agriculture by better opportunities elsewhere, pushing up labor costs in agriculture and making mechanization more attractive. Chinese farms have so far, by and large been sufficiently large to capture the existing economies of scale, such as those arising from oxen and small hand pushed tractors. However, as labor costs rise, it will become profitable to substitute larger-scale machinery for small hand pushed ones and oxen, putting pressure on the farm size.

PRESSURE ON FARM CONSOLIDATION FROM RISING OFF-FARM WAGES – SOME RUDIMENTARY ARITHMETIC

The pressure on land consolidation emanating from intersectoral labor competition in China is nicely illustrated by the following rudimentary numerical example.^a It also highlights the practical limitations for large scale farming in China. Based on data from the China National Development and Reform Commission (NDRC), average income per ha from paddy rice production almost tripled between 2003–2008, from 1353 (2000RMB)/ha in 2003 to 3630 (2000 RMB) in 2008, rising by about 2300 RMB in total (of which 600 RMB/ha were due to subsidies and 90 RMB/ha due to the abolishment of agricultural taxes in 2005). Without subsidization, after tax net rice income per ha only doubled—rising by about 1500 RMB, hinting at the rising importance of agricultural subsidization as a response to keep farm incomes up with non-farm ones.^b

At an average farm size of 0.6 ha and assuming only rice were produced, this suggests an average increase in net income between 2003 and 2008 of 1380 RMB per farm household (with subsidization/taxation) and of 900 RMB (without subsidization). Net average increases in cereal income per ha of a similar magnitude were found for the other cereals (somewhat higher for wheat, and somewhat lower for maize and soybeans).^c Compare this with an increase in average annual real disposable income per rural and urban *household* between 2003–2008 of 8552 and 21,924 RMB (in 2000 RMB) respectively (assuming an average households size of 4 in rural and 3 in urban areas). In other words, and assuming constant returns to scale, to match the average rural and urban income increase, rice farms should have expanded 8.5 or 22 times respectively (without subsidization). With subsidization, they should have expanded 6.2 times (to 3.6 ha on average) or about 16 times (to 9.6 ha) respectively. Clearly, this is massive, and such a pace of land consolidation is unfeasible, without draconic interventions. To picture this, note that to increase one farm's size from the average 0.6 ha to 3.6 ha in five years time, five farmers ($3 \text{ ha} = 5 \times 0.6 \text{ ha/farm}$) would have to give up farming, or one farmer among any six farmers should quit farming each year. Such an exodus of farm labor is clearly unsustainable, causing massive disruptions on both the rural/sending side as well as on the urban/receiving side.

Overall, three important insights emerge from this simple arithmetic. First, China's cereal production on its small and fragmented farms proves still profitable as such (excluding labor costs), despite doubts to the contrary by some. Second, subsidies are becoming an important part of cereal farming income—and they have continued to increase since 2008. Third, a substantial share of China's cereal farms has become too small to keep up with income growth outside agriculture and generate a comparable standard of living from cereal farming alone. Assuming constant returns to scale, only (rice) farms of 3.7 ha or more ($=8552/1380 \times 0.6$) would have generated a similar income growth as what has been observed on average among rural residents. Without subsidies, only full time (rice) farms of 5.1 ha would have yielded similar income growth. Such larger farm holdings do exist, especially in the corn, wheat and soybean surplus producing regions of the North East (e.g. Heilongjiang and Liaoning). But, they are generally a minority, and most current farm holdings do not reach this size.^d

In short, cereal production on the current farm structure is under substantial economic pressures from intersectoral competition. Against this background it is no surprise that in 2005 non-farm income accounted on average already for 40 percent of farmers' income.

^a Numbers are taken from Fang (2010).

^b Without subsidization, net income was estimated at RMB 2940/ha (in 2000 RMB) in 2008, up from 1447 (2000 RMB) (before taxes) in 2003.

^c Note that the growth in returns is not unduly driven by the choice of the beginning and especially the end period. Indeed, world cereal prices spiked in 2008, but as explained in Fang (2010), China stabilized its grain prices during the 2008 crisis, while allowing a gradual increase thereafter to bring them more in line with world markets again. China's domestic grain price index (2000=100) stood at 95, 147 and 173 in 2003, 2008 and 2010 respectively; the international grain price index (in RMB) evolved from 120 in 2003 to 207 in 2008 and 183 in 2010. During the 2008 crisis, China's domestic rice prices were kept well below the 2008 world market price and have been kept well below the world rice market since. The 2008 wheat and maize world price surges were also passed through only partially (an increase of 17 and 23 percent in 2008 compared with 2006, while world market prices increased 51 and 61 percent) (in Chinese RMB terms). Soybeans tracked the world market prices throughout.

^d Some household survey based descriptive statistics of differences in farm size and degree of mechanization and capital intensity across regions can for example be found in Chen, Huffman and Rozelle (2009) (Table 1).

A dual farm structure may thus arise, with part time farming predominant in the mountainous areas and larger mechanized farms characterizing future agriculture in the plains. To enable part time farming in mountainous areas, off-farm employment opportunities will be necessary in neighboring towns and cities, underscoring the importance of small and medium town development in overcoming the farm problem, especially in the more mountainous areas. Land reforms, institutional innovations, such as machine rings, and more widespread access to credit will further be necessary to enable small to medium sized family farms to stay commercially viable within this more mechanized environment. Otherwise, the landscape will be largely captured by large scale, capital intensive corporate farms that generate little rural employment and increase pressure on urban migration. While that may resolve the food, it will not resolve the farm problem, increasing pressures to adopt OECD type agricultural policies of subsidization and protection even further (Box 4).

Appreciation of the Renminbi will increase international competition. As China continues to rebalance its drivers of growth from exports to domestic private consumption (12th Five-Year Plan) and proceeds with the gradual appreciation of its currency, international exporters will become more price-competitive on its domestic market. The consequences of this will not only be felt in merchandise trade and financial markets, which tend to dominate the media's attention, but also in the agricultural commodity markets. This may further induce domestic calls for protection, subsidization or other measures to curb the inflow of agricultural commodities.

As illustrated in Figures 12 and 13, land and water intensive cereal farming is most vulnerable to Renminbi appreciation, while more room for maneuver is left for Chinese fruits and vegetables, consistent with the global distribution of factor endowments and increased trade. Further appreciation will thus pose an

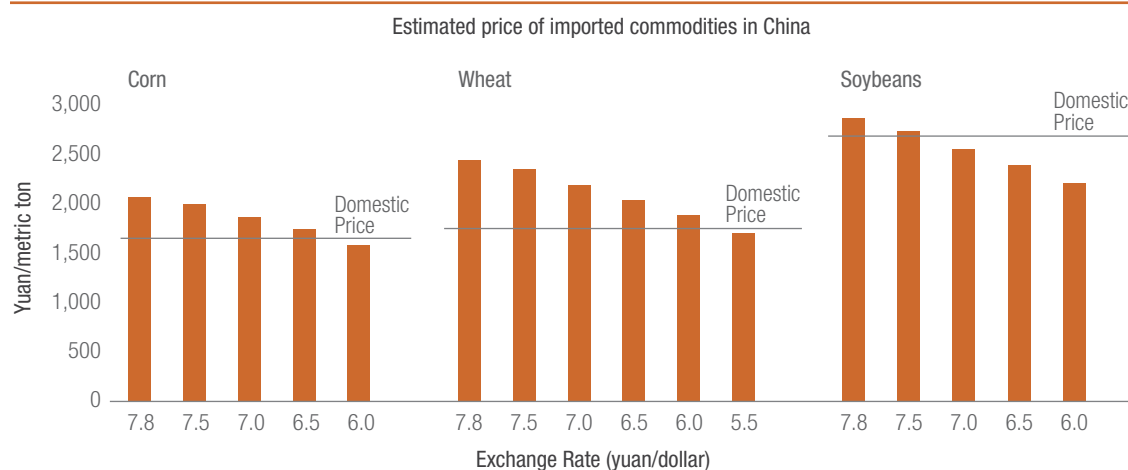
BOX 4

RISING RURAL LABOR COSTS RAISE SUBSIDIZATION AND PROTECTION – THE POST-WAR EXPERIENCE IN JAPAN

The experience in Japan is illustrative of what is awaiting China as its rural labor costs increase and pressures to mechanize mount, while the structural transformation of its economy away from agriculture outpaces the occupational transformation of its rural labor force and the consolidation of its farms. Studying Japan's agricultural transformation, Hayami and Kawagoe (1989, p237–8) conclude: "(...) a severe adjustment problem will await [developing countries] as they will successfully enter the stage at which the real wage rate begins to rise sharply. At that stage, agricultural production will be subject to increasing returns. But, the transfer of labor to the non-agricultural sector and the expansion in farm size will proceed slowly, even without severe regulations on the land market, as depicted by the experience of Western economies. Meanwhile, the comparative advantage will shift away from agriculture in countries with relatively rapid increases in industrial as compared to agricultural productivities. The lag between the loss of comparative advantage in agriculture and the intersectoral re-allocation of labor can be expected to give rise to agricultural protectionism in such countries. This has been the experience in Japan [Hayami (1988)] and may well be repeated by newly industrializing countries, especially those located in areas of high population density in Asia. Indeed, it has already occurred in Korea and Taiwan [Anderson and Hayami (1986)]." The increase in China's producer support estimate (PSE) from 3 to 17 per cent between 1995–97 and 2010 and the increase in the ratio of the producer to border price (the nominal protection coefficient) from 1.01 to 1.06 between 1995–97 and 2008–2010 are striking reminders of the pertinence of these observations for current China.

FIGURE 12

CHINESE CEREAL PRODUCTION VULNERABLE TO APPRECIATION OF RENMINBI

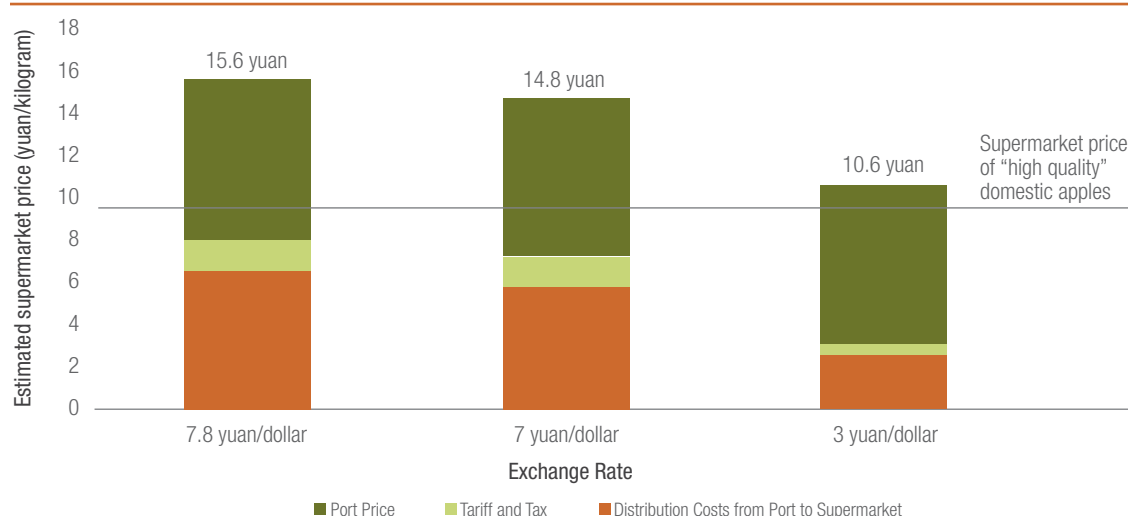


Source: Gale and Tuan (2007).

Note: Based on December 2006 prices. Calculations assume prices, tariffs and taxes, and shipping rates prevailing in December 2006 remain constant.

FIGURE 13

FRUIT AND VEGETABLE PRODUCTION NOT SO VULNERABLE TO APPRECIATION OF RENMINBI



Source: Gale and Tuan (2007).

Note: Calculations assumed constant US\$ port price of \$.83/kg and a constant distribution cost of 7.6 Yuan/kg. Tariff on apples is 10 % and value added tax is 13%. Port price obtained from December 2006 China customs statistics. Supermarket prices obtained from Tianhui Supermarket Fruit Prices.

important additional challenge to the competitiveness of China's cereal farms (the farm problem) and its cereal self sufficiency objectives (the food problem), not unlike what happened in Japan. Indeed, the dramatic increase in soybean imports since 2006 from about 28 mmt in 2006 to more than 56 mmt in

2011 and the incipient increase of maize imports (estimated at up to 3 mmt in 2011 after many years of net exports) to meet the rising demand for animal feed, may not be coincidental. In the summer of 2007, the Renminbi passed the 7.5 Renminbi/US\$ mark at which US soybeans become competitive on the

Chinese market, according to the calculations reported in Figure 12.⁶⁷ In the spring of 2011, it breached the 6.5 Renminbi/US\$ mark at which US maize was considered to become competitive.

To further appreciate the potential importance of China's expected exchange rate appreciation for the future development of its agricultural sector, it is useful to recall the experience of Japan. As China, Japan has also followed an export led growth paradigm and as in China, cereal production has also been concentrated on very small farms. When Japan embarked on export led development in the 1950s, the Yen was set at 360 Yen/\$US. It remained at this rate throughout 1971, when the gold standard was abolished. By then, it had become undervalued (and increasingly criticized for it). The Yen has continued to depreciate since to about 80 Yen/US\$ nowadays.⁶⁸ During the course of this transition, Japan also developed one of the most protected agricultural sectors in the world.⁶⁹ This is not to say that a similar rate of appreciation is to be expected in China or that it will affect

China's agriculture with the same strength.⁷⁰ Rather, it highlights that further Renminbi appreciation is likely, and that this is likely to affect the competitiveness of China's agriculture over the coming decades, especially the competitiveness of its cereal production. This is bound to further increase calls for support.

Climate change increases uncertainty in the production environment. The challenges the economic pressures pose on the agrarian production system to shift from a labor intensive to a more capital intensive system must be addressed in increasingly fragile ecosystems and in the face of rising climatic uncertainties. Some simulation models suggest that global warming is likely to be harmful to rainfed farms, but beneficial to irrigated ones, with the net impacts only mildly harmful at first, but growing over time (Wang et al., 2009). However, the impacts vary across regions, and the indirect effects of possible changes in the water flows, which are quite real, are not captured in these particular models. Indeed, as discussed above, the most binding environmental constraint is

⁶⁷ Chinese soybean import increased from being quasi zero in the mid 1990s to about 28 mmt in 2006. Since then, Chinese imports have doubled again to 56 mmt in 2011, accounting for more than 57 % of the world's total exports today. The initial increase in China's soybean imports was first especially sourced from Brazil, which saw its soybean exports rise from about 8 mmt in 1996 to 26 mmt in 2005. Since then, the US have seen their soybean exports rise from about 31 mmt in 2007 to about 41 mmt in 2010. During the first half of the 2000s, when the Renminbi was above the 7.5 Renminbi/US\$ mark, their exports hovered mostly between 25 and 30 mmt (USDA, 2011). In sum, while Renminbi appreciation is not the only reason for the increase in China's soybean imports over the past 15 years, it has undoubtedly contributed to its dramatic increase over the past 5 years. Early on, imports were facilitated by the abolishment of the monopoly of state-trading companies on soybean imports in the late 1990s. As an important water user, soybean imports also help substantially in mitigating water needs (see further Figure 15), though this may have been a fortunate coincidence.

⁶⁸ Kokko (2002). By way of comparison, the Renminbi was devalued by 50 % from 5.8 to 8.7 Yuan/US\$ in 1994. After having been fixed at 8.3 Yuan/US\$ since 1995, the Renminbi started to gradually appreciate in June 2005 to reach 6.8 Yuan/US\$ in July 2008 (an appreciation of 18%). Stopped in July 2008 to fight the consequences of the global financial crisis, appreciation of the Renminbi picked up again in May 2010 to reach 6.38 in August 2011 (or 23% appreciation compared with 1995). Analysis of the prevailing economic forces suggests that further appreciation is likely (IMF, 2011).

⁶⁹ World Bank (2007).

⁷⁰ In addition to its first round effects of making international imports cheaper, given the size of the Chinese market, sizeable increases in China's cereal imports following an appreciation of the Renminbi are bound to increase world market prices, thereby also raising the competitiveness of its domestic production. Second round effects are thus likely to take away some of the edge of the appreciation's first round effects. This may not have been the case for Japan, whose population is only one tenth the size of China's.

likely water, especially in the northern plains, jeopardizing potential production gains from mechanization.

These, and other simulations, underscore that at the local and regional scale, rising uncertainty about the production environment is the defining feature of climate change. Future temperature and precipitation patterns are uncertain and extreme events become more likely. This adds an important layer of uncertainty to a production system that is intrinsically uncertain to begin with. Adaptation will have to be part of the answer to provide relief, while mitigation in agriculture will also need to be embraced as part of China's international responsibilities.

3.3.2 Changing Demand Dynamics

Cereal feed demand is propelling the overall demand for grain going forward, while

food cereal demand is halting. An important corollary to the ongoing urbanization process is the shift away from grains as households become richer and move to the cities. Chinese diets now include fewer grain products like rice, bread, and noodles, while consumption of meats, eggs and dairy has risen. In addition to income growth, urbanization in itself is also an important driver of this shift, with average food grain consumption among Chinese urbanites on average only a third of their fellow rural countrymen.⁷¹ This is reflected in the negative income elasticities of demand for rice and wheat in urban areas, compared with the small, though still positive income elasticities observed in rural areas (Figure 14). In light of the supply constraints and uncertainties described above, this does provide some relief for China's pursuit of self sufficiency for rice and wheat. The Chinagro II model predicts that consumption growth of these two grains between

FIGURE 14

INCOME ELASTICITY OF DEMAND (IN 2006) FOR RICE AND WHEAT IS LOW AND IN URBAN AREAS NEGATIVE; INCOME ELASTICITY OF DEMAND FOR HIGH VALUE CROPS IS POSITIVE, AND ALMOST ONE FOR DAIRY



Source: Huang and Rozelle (2001).

⁷¹ Lohmar, Gale, Tuan and Hansen (2010).

2005–2030 will be virtually zero and easily met by domestic production.⁷²

The income elasticities for oils, sugar, vegetables and fruits, and meat, on the other hand, are positive and similar in both rural and urban areas (between 0.4 and 0.6). The income elasticity of demand for dairy is estimated at around 1, which is consistent with its more recent boom in domestic production. Annual meat consumption per person is expected to increase by another 20 kg from about 53 kg/person/year in 2010 to about 73 kg in 2030, up from about 25 kg/person/year in 1990. With expected population growth still positive till about 2025–2030 and average feed-meat conversion ratios substantially above one (estimated at 4.7 for pork, 4 for beef, 2.8 for poultry and 1.15 for milk on average)⁷³, the demand for feed grain (maize, soybean) is rising rapidly. It is expected to remain strong throughout the period under consideration here (on average 1–1.5 % per year over the 2005–2030 period).⁷⁴

With domestic cereal supply struggling to keep up with this demand, China has dramatically increased its soybean imports, from virtually nothing in the mid 1990s to about 10 mmt in 2000, 28 mmt in 2006 and 56 mmt in 2011 (much of it from Brazil first and increasingly also the US). The next (feed) crop under pressure is maize, with China switching its net trading position from being a net exporter (of 3–15 mmt over most of the past decade) to becoming a net importer (an

expected 3 mmt in 2011). The grain self sufficiency strategy to resolve the food problem is being challenged.

Dietary shifts also open up important new and remunerative employment opportunities for farmers,⁷⁵ both directly through the more labor intensive production of meat and dairy, fish, and fruits and vegetables, as well as through the increased demand for (unskilled) labor in the downward agro-processing industries and marketing. There are however important economies of scale in these downstream industries, promoting vertical integration of the supply chains to ensure a stable supply of high quality agricultural products. These only grow as consumer demand for quality and food safety increases, and food standards tighten, putting the smallholder farm model under pressure.

The pressures for consolidation have not prevented smallholders to participate in the growing fruit and vegetable sectors.⁷⁶ Almost all purchases of fruit, vegetables, and nuts have been by small traders. Livestock products, particularly pork raised by households, are also traded by small traders, though there is an increasing contingent of large-scale animal farms and agri-businesses. As economies of scale grow and standards tighten, the pressures for consolidation and vertical integration will continue to grow.⁷⁷ Adequate institutional innovations (including through producer associations) will become increas-

⁷² Keyzer and van Veen (2010). This model does not account for climate change.

⁷³ Zhang, Wei, and Malcolm (2008).

⁷⁴ Keyzer and van Veen (2010). While in the mid 2000s, about half of China's feed consumption was still met through traditional local feeds, such as grasses, crop-by-produce and crop-residuals, as future growth in livestock production is largely met through intensive animal husbandry (stall-fed poultry and pigs in large production units), the demand for cereal feed is also rising rapidly (Fang and Fuller, 1998).

⁷⁵ Keyzer and van Veen (2010) predict farm value added from livestock production to grow at more than twice the rate as farm value added from cereal production (5.1 versus 2.2 percent per year respectively). While both are still below non-agricultural growth (fixed at 6–7%/year), the gap is substantially less for livestock production.

⁷⁶ Wang et al. (2009); Huang, Otsuka, and Rozelle (2008).

⁷⁷ Reardon, Timmer and Minten (2010).

ingly necessary to enable smallholders to connect to these modern supply chains, so that they can maximally benefit from the new growth opportunities, while adequately addressing safety and environmental concerns and ensuring supplies of high quality. This will be critical in overcoming the farm problem.

Increasing amounts of animal waste from intensifying livestock production aggravate the field problem and increase animal and human health hazards. Most of the growth in livestock production will be concentrated on large intensified production units in close proximity to its consumers in the towns and cities to reduce transportation costs. This results in a massive nutrient transfer from the cereal feed producing areas in the urban hinterlands and the northern and northeastern regions to the livestock producing areas in the peri-urban and urban areas. It breaks the natural local nutrient balance in both the nutrient producing and consuming areas. Massive imports of cereal feed, inducing a concentration of intensified livestock production along

the coastal areas to reduce transport costs, will only aggravate the challenge.

Without proper regulation and animal waste management practices, atmospheric emissions of excess nitrogen and nutrient leaching to ground and surface water will aggravate the existing field problems from over utilization of chemical inputs. To illustrate the scope of the challenge, Table 3 presents estimates of the excess nitrogen and phosphate supply from both chemical fertilizer use and confined livestock production per ha crop and orchard land in 2005 and 2030. These are highest for nitrogen and in 2030 they amount to about 200–276 kg per ha in the East, Central, South and Southwest regions (Table 3). A counterfactual exercise with farmers optimizing farming practices and chemical fertilizer application in line with the latest agronomic insights available, still points to an oversupply of 40 kg of nitrogen per ha, and much more in the East region, but no longer an excess release of phosphates (results not reported here).⁷⁸

TABLE 3
EXCESS NUTRIENT SUPPLY¹⁾ IS SUBSTANTIAL, ESPECIALLY FOR NITROGEN, WITH LITTLE DECLINE IN SIGHT

Kg/ha crop & orchard land Region	Nitrogen		Phosphate	
	2005	2030	2005	2030
North	223	165	88	71
Northeast	88	76	16	13
East	252	263	75	90
Central	221	197	94	92
South	219	276	74	115
Southwest	192	211	70	84
Northwest	68	73	23	31
China	171	166	60	66

Excess nutrient supply = estimated total nutrient supply from chemical fertilizer nutrient application and confined livestock production minus the maximum nutrient uptake by crops.

Source: Fischer, Ermolieva and Sun (2010).

⁷⁸ These numbers are not reported in Table 3, but can be found in Fischer, Ermolieva, and Sun (2010). See also Fischer et al. (2010).

The environmental pressure posed by the intensification and geographical concentration of animal husbandry is extremely high, but there is also hope. Indications are that current rates of fertilizer use are often excessive from a purely financial perspective—much less an environmental perspective—given scope for potentially rapid change. Indeed, the concentration of livestock in larger production units can facilitate the enforcement of regulations and proper animal waste management practices.⁷⁹ Relocation of intensified animal production to less densely populated areas for example through zoning, as in Thailand,⁸⁰ will also be important to address the increased risk of animal and human pandemics.

3.4 THE OUTLOOK IN SUM

Rising supply constraints pose deep challenges; changing demand patterns provide some opportunities, if managed well. Rising water scarcity, competition for land and labor, and a changing climatic environment are pushing up production costs and risks, resulting in upward pressures on domestic food prices, while Renminbi appreciation makes international agriculture more competitive. These developments increasingly put domestic agriculture in a bind, especially land intensive and water consuming grain production, while the demand for feed grains (maize and soybeans, not rice or wheat) is rising rapidly, following the rising demand for livestock products. As a result, the food problem is resurfacing with the grain self sufficiency model as primary vehicle to resolve it, increasingly challenged. Increasing reliance on trade

to bridge the growing feed grain gap, as already practiced through the rapid expansion of soybean imports provides one alternative. Whether to extend this to other feed (and/or food) grains such as maize presents an important policy choice for China moving forward in addressing its food problem.

Rising rural nonfarm wages are further challenging the smallholder farm model to capture the economies of scale from mechanization and provide comparable earnings with off-farm employment. Opportunities for mechanization and land consolidation are also more limited in the mountainous areas. These evolutions are only adding to the prominence of the farm (income) problem, with the field problem lurking in the background as over use of chemicals is polluting waters and air (most precipitously in the Eastern and Southern Regions) and land degradation is reducing soil fertility (especially in the West). These environmental pressures will be exacerbated through the concentration of intensified livestock production in the peri-urban areas in response to the growing demand for livestock products.

Nonetheless, the increasing demand for more labor intensive high value products (including livestock products) also provides important opportunities to address the farm problem (in addition to migration and mitigation), if appropriate institutions can be developed to enable smallholders to link in to the increasingly tight value chains. These are the challenges ahead of Chinese agriculture as China charts its way to becoming a harmonious, high income society by 2030.

⁷⁹ There is also a national smallholder biogas program focused on households with at least two pigs. But the trend is towards bigger, more concentrated animal and waste management units

⁸⁰ World Bank (2007). The concentration of animal production in urban and peri-urban areas increases risks of pathogen cross over across species following more intensive animal-human interaction. This poses a threat to human health, as the 2003 Avian Flu outbreak reminded us.

TOWARDS MODERN COMMERCIAL SMALLHOLDER FARMING

To achieve a modern commercial smallholder agriculture that achieves national food security, narrows the rural-urban income gap, and renders the natural resource base more sustainable, the vision for China's agriculture 2030, six areas of actions present themselves:

1. revisit China's food security objectives—in particular, self sufficiency targets for maize;
2. rationalize factor markets and use institutional innovations to empower smallholders;
3. continue to strengthen the provision of (rural) public goods—agricultural technology, rural education and infrastructure, and food safety;
4. support rural incomes while avoiding the subsidy trap;
5. improve agricultural water and animal waste management;
6. manage risks better—adapt to and mitigate the effects of climate change.

The following sections discuss why and how certain policy actions in each of these areas can make a critical difference in modernizing agriculture in support of the creation of a harmonious and high income China by 2030.

4.1 REVISIT FOOD SECURITY OBJECTIVES

Given the supply and demand trends described above, China's approach to food security should allow greater import reliance for maize, even if targets for rice and wheat are maintained. Like many countries, China sets a premium on food sovereignty, i.e. maintaining independent control over its food supply at all times. The political sensitivity of household access to cheap staple grains and geopolitical considerations have in the past often compelled large nations like China to strive for food self sufficiency to maintain such independent control, as opposed to relying on the markets to secure their supplies. In this architecture, policies to promote domestic production are coupled with large buffer stocks to compensate in case of domestic harvest failures. International trade is called upon to equalize the residual balances (gaps or surpluses), only at the margin, and when really necessary.

Securing one's food supply through food self sufficiency can come at a high cost. When countries do not have a comparative advantage, imports may be cheaper, and buffer stocks (especially

for rice) are costly to maintain.⁸¹ But, food self sufficiency provides a sense of being in control of one's food destiny, and thus a sense of being food sovereign, which market mediated food security does not.⁸² One appears no longer susceptible to food production and trade choices of other nations. But, one remains equally susceptible to domestic weather shocks. To the extent that world markets may still need to be relied upon in case of large domestic production shortfalls, it could even be argued that one becomes more susceptible to (uncontrollable) domestic shocks as world markets will now be less prepared to cater to such large and sudden increases in demand.

While having been surprisingly successful in achieving grain self sufficiency for most of the reform period, after several years of taking marginal land out of rice and wheat production in the 1990s in response to a decade long decline in grain prices, the ability to maintain grain self sufficiency became a concern again in the mid 2000s. However, following greater selectivity in agricultural land conversion, a rapid increase in agricultural subsidies, and an expansion in agricultural R&D investment, overall rice and wheat production levels edged up. They now almost reach their peaks of the late 1990s again. At the same time, import dependence for feed grains has been growing (especially for soybeans), while exports of maize gradually declined, with China even becoming a net importer of maize in recent years, albeit still in small amounts. But, worries about market reliance remain, not helped by the 2008 and 2011 international cereal price hikes and the recurrence to restrictive trade practices by exporters. Should China continue on its current path of greater reliance on world markets for feed grains, including maize?

The efficiency (market pressures), equity and ecological considerations reviewed in section three all suggest it should. To begin, given its land and water resource endowments, China has no international comparative advantage in land and water intensive cereal production. Competition for land from other sectors and rising water scarcity are increasingly squeezing profits, while putting upward pressures on grain prices for consumers. Rapidly increasing nonfarm wages are further making it harder to earn a decent and comparable living on the farm, while Renminbi appreciation is making international maize more competitive and WTO regulations limit space for distortionary and inefficient protectionist support or subsidization. Bans on agricultural land conversion would hinder the necessary development of other sectors and economic growth (Box 5). Sole focus on capital intensive production through mechanization on large scale farms to overcome labor costs would not generate the necessary rural jobs, exacerbating, instead of alleviating, the farm income problem. Moreover, more erratic weather patterns following climate change are bound to make annual domestic production more volatile. This would increase the need for occasional reliance on the world market (as in 2011), unless even larger and more costly buffer stocks are maintained. Limited ex ante engagement with the world market also leads to thinly traded world markets, which will subsequently be less able to absorb sudden demand shocks in case of domestic weather and crop failures.

The massive increase in soybean import observed over the past decade (exceeding 50 mmt/year since 2009) has been a rational response to these rising resource constraints,

⁸¹ Dawe, et al., (2010).

⁸² By way of comparison, people typically consider car, a safer medium of transport than airplanes, despite a plethora of evidence to the contrary, as the former provides more opportunities for exercising control than the latter.

BALANCING LAND USES BETWEEN AGRICULTURE AND NON-AGRICULTURE

Industrialization and modern development demand that land conversion continues. But, given more rational land conversion practices, this can also benefit agriculture, rural residents and urban expansion alike. Rural land is under collective control. The State however has exclusive power to acquire rural land and transfer it to urban users and the existing land acquisition practices are biased towards urban development. They further limit the share of the collective and the rural land use holder in the appreciating value of land that enters the urban market. This is an important missed opportunity in resolving the rural-urban divide and the farm income problem. It partly emanates from the relatively unbalanced revenue and expenditure assignments of local governments following the abolition of agricultural taxation. This has induced local authorities to seek extra-budgetary income to foster local growth, which has been a key criterion for the promotion of local political leaders. Reducing the incentives for land conversion, better rules for offsetting land development, and a more transparent implementation of land acquisitions can go a long way in fostering a more rational land use for agricultural and nonagricultural purposes. It will likely also be more successful in effectively and efficiently maintaining the 120 million ha of cultivated land currently set aside under the 'Red Line' policy.

The combination of the State's power to expropriate rural land and convert it to urban use as well as its monopoly in the urban land market enable local governments to rely heavily on the income generated from land transfers to supplement regular budget funds and meet their expenditure needs. Local governments also increasingly rely on mortgage loans using requisitioned land as collateral through land banks.^a Both practices have resulted in the aggressive requisitioning of rural land resulting in a waste of land resources and unstable growth processes. These problems can be addressed by reforming the current system of local finance through a gradual introduction of property taxes that would reduce their reliance on extra-budgetary financing sources.

Second, a more adequately designed land development allowance policy combining quota for cultivated land conversions with subsidies for off-setting agricultural land development elsewhere can further contribute to emulating nationally first best land use allocation between agriculture and non-agriculture in the face of incomplete decentralization and inter-jurisdictional competition for mobile capital. The possibility and need for offsetting the conversion of cultivated land by land development for agriculture elsewhere already exists. It could be improved through an explicit set of guidelines linking land conversion quota to land development efforts at the provincial government (Chau and Zhang, 2010).

Finally, the process of land acquisition needs serious reform in three dimensions. First, the current ambiguous limits on the purposes for which the State can use its powers of compulsory acquisition need to be clarified and narrowed. Second, the standards, variation and distribution of compensation for land acquisition need to be rethought. Finally, the process of requisition needs to be made more transparent, with realistic timetables and with possibility of appeal. Overall, fairer benefit-sharing approaches in the urbanization process could be pursued by gradually granting access for collectives or rural land use rights holders to urban land markets, while at the same time, phasing out the State's monopolist power in the land market.

^a Unrecorded local government debt is rapidly becoming a threat to the stability of China's financial system. It has increased to 3.5 trillion yuan (\$540 billion) according to the rating agency Moody (July 5, 2011), raising the estimated local government debt to Chinese banks to 8.5 trillion yuan.

not least this of water. With 3203 m³ water required per ton output (or 3203 l/kg), soybean production is among the most water intensive crops. It yields at the same time

among the lowest value per cubic meter water used (6 US cents per cubic meter (Figure 12)). Importing soybeans thus equates with importing vast amounts of water, giving rise to a

virtual trade in water.⁸³ This relieves pressure on the water tables in the northern plains, where water scarcity is felt most.⁸⁴ It also alleviates the need for the massive, ecologically disruptive, and economically costly south-north water transport infrastructure.

While not as thirsty as soybeans, at around 850 water m³/ton output (or 850l/kg), maize is also a large user of water and it yields an equally low return on water use (about 0.08 US\$/m³), just like the other cereals. Most fruits (except citrus) and vegetables (including potatoes) on the other hand, are much less water intensive. They also yield much higher returns per cubic meter. From this perspective, the move to relax self-sufficiency targets on soybeans first may thus have had important unintended positive effects on the water front. It was also facilitated by the appreciation of the Renminbi, which already rendered US soybeans competitive on China's markets at an exchange rate of around 7.5 Yuan to the US\$ (Figure 12) compared with 6.5 RMB/US\$ for maize. Against this background and with the exchange rate now at 6.3 RMB/US\$, it makes economic, ecological and social sense to extend the current strategy adopted for soybeans and relax self-sufficiency requirements for maize, the other main animal feed,⁸⁵ while at the same time expanding the exports of fruits and vegetables, which require less land, yield higher

rural employment opportunities and much higher returns per ha (important for resolving the farm problem).

To be sure, rising corn imports by China would exert upward pressures on the world market price, especially if there wasn't a commensurate supply response elsewhere. When it concerns a moderate increase, as proposed here, and if pursued gradually and predictably, coupled with increased support to international agricultural research institutes to boost production worldwide and investment in African agriculture and diplomacy, it would also provide the world's production system time to adapt and disruptions in the world markets could be avoided (Box 6). By way of comparison, the increase in China's soybean imports from virtual nothing in 1995 to about 30 mmt in 2005 has been managed without major disruptions in the world market prices during that period, in this case largely through an expansion of Brazil's production capacity in its Cerrado, most of it supplying the Chinese market.⁸⁶

A limited effect on world prices is also what is predicted by 2005–2030 simulations based on the computative general equilibrium Chinagro II model that enables endogenous reactions of world prices to changes in China's net trade flows.⁸⁷ In particular, using the OECD-FAO projections in Agricultural

⁸³ Liu, Zehnder and Yang (2007) estimate that China's total net virtual water import implied in its grain trade increased massively over the past decade from between 20 to 30 billion cubic meters per year during the 1960–1990 period to over 70 billion cubic meters in 2004.

⁸⁴ While about two fifths of China's total soybean production comes from Heilongjiang (the Northeast Region), where water scarcity is less of a concern, about one fifth comes from the five provinces in the northern plains (Hebei, Jiangsu, Anhui, Shandong and Henan).

⁸⁵ While maize is a major feedstock in pork production, soybean has been particularly important in aquaculture.

⁸⁶ Brazilian Agriculture. The Miracle of the Cerrado – Brazil has Revolutionized its Own Farms. Can it Do the Same for Others? *The Economist*, Aug 26, 2010.

⁸⁷ See Keyzer and van Veen (2010) for a detailed description of the Chinagro II model and different scenario simulations. Chinagro II results from a 5 year collaborative EU-funded effort (Chinese Agricultural Transition – Trade, Social and Environmental Impacts) – CATSEI led by the Center for World Food Studies at the Free University of Amsterdam. The Chinagro model is a 17-commodity, eight region general equilibrium welfare

QUALITATIVE PERSPECTIVE ON A MODERATE, GRADUAL EXPANSION OF MAIZE IMPORTS BY CHINA

Chinese maize production increased by 63 mmt between 2000 and 2010 (from 114 mmt to 177 mmt or 6.3 mmt per year); during the same period, the world's production (exclusive China) increased by 174 mmt or 17.4 mmt on average per year (from 591 to 765 mmt). Global maize trade increased from 70 to 90 mmt (or about 10–11% of world production). Meeting one third of China's growth in maize demand through imports (keeping growth in China's demand constant at 6.3 mmt per year and abstracting from the animal feed substitution possibilities discussed further below and keeping the world's growth in demand constant at 17.4 mmt) would thus require a 12 percent increase in the world's maize production growth ($=2.1/17.4$ mmt). This is undoubtedly substantial, but not unlike what has been observed in the soybean markets before, where all of China's 30 mmt growth in soybean demand between 1995 and 2005 was produced outside China, with nominal world soybean prices (in US\$) in the mid 1990s and mid 2000s at similar levels (around 300 US\$/ton).

It should also be seen in light of the estimated untapped production potential. An estimated 83.3 million ha uncultivated non-forested land with potential for maize production is still available worldwide, of which 20 million in Argentina and Brazil alone, where current yields are 6.5 and 4.1 ton/ha (Box 7). This suggests that it should be feasible to meet China's future growth in import demand of maize (put at a third of its assumed annual growth of 6.3 mmt) for a number of years, without excessive impacts on world prices, provided clear and predictable market signals for investors. Twenty years of a third in China's growth in demand coming from imports (about 42 mmt) would put China's self sufficiency rate for maize still at 86% ($=261/303$).

Outlook 2009–2018 to capture expected world demand and supply with several upward adjustments for grains, feed and meat, the baseline Chinagro II scenario predicts that China would import about 16 million tons of maize by 2030, assuming that government tariff policies would allow large volumes of imports at low tariffs. Carbohydrate feed imports (feed other than maize that is rich in carbohydrates, such as those based on tubers and minor grains) would rise from 1 to 14 million tons (in grain equivalents) and protein feed imports (feed rich in proteins such as oilseed cakes, wheat and rice bran) from

24 to 58 million tons (in cake equivalents). As a share of demand in China, these import volumes are not excessive (52 % and 42 % for edible oils and protein feeds respectively and less than 20 % for the other shares). Yet, they can be large for the rest of the world, with carbohydrate and protein feed imports by China accounting for 30–40% of world trade and maize and edible oil imports accounting for 15–20 percent. Nonetheless, based on separate simulations using the worldwide GTAP model, world feed prices (including maize) in the baseline scenario only rise by about 5 % in 2030 compared with 2005.⁸⁸ But, the feed

model with farm supply represented at the county level (2,885 counties). For each county, the outputs of 28 activities and nine land use types and livestock systems are accommodated. Consumption is modeled at the regional level, separately for urban and rural population, each divided into three income groups. The model is calibrated on the 2005–2010 database and is quite unique in its high degree of spatial and social detail. It assumes 6–7 percent nonagricultural growth, moderate population growth (to 1,436 million people by 2030) with urbanization rising to 60%, continued intensification of the livestock sector with higher feed efficiency but lower use of residual animal feed, further trade liberalization, and the introduction of grain price support.

⁸⁸ It concerns the average effect on world prices of the expected increase in China's import based on the base scenario simulation. Relative world prices for maize, carbohydrate feed and protein feed would increase by 5.7%, 3.3% and 6.5%, respectively, or about 5 % on average. The effect is moderate partly because of feedback effects from a rising world price on China's domestic production.

grain price rise may be higher if imports are higher (as discussed in Box 6). This is an important area for future analysis.

But predicting the impact of a relaxation of China's maize self sufficiency ambitions is a complex matter, which ultimately requires a general equilibrium approach, which should also include the effects of changing climatic patterns. From the qualitative back-of-the-envelope calculations above, it is concluded that given the economic and ecological cost pressures on domestic cereal production, how a gradual, predictable and moderate increase in China's maize imports would affect world market prices in today's tight food markets deserves to be explored further in a computative general equilibrium setting. This fell beyond the scope of this review, but the first insights regarding the effects on the world prices provided by the CATSEI project are reassuring in this regard.

But can the markets be relied upon to deliver the necessary maize supply at relatively stable prices? Given appropriate and timely engagement with the world market and exporting countries, the answer is yes. First, being primarily used as animal feed, the political sensitivity of maize is less pronounced than this of rice or wheat, the core staples. World maize markets are also more liquid and diversified than those of rice, with financial instruments for hedging and securing supplies well established by now.⁸⁹ And if feed grain shortages arise, domestic and imported non-grain feeds (e.g. cassava and potatoes) remain an alternative, as does the import of live animals or processed

animal products itself.⁹⁰ Concerning the former, the domestic production of potatoes also provides a much more water efficient alternative for animal feed (see Figure 15). Useful lessons could be learned from the experience of Anding County in Gansu, as it developed from a low productivity wheat producing area into one of China's three leading potato clusters, thereby providing important and remunerative employment opportunities for its farmers.⁹¹ Meat and dairy imports are also attractive from the "field" perspective as the China's virtual water content of meat and dairy products are much higher (estimated at 6.7 and 4.3 m³/ton) than this of animal feed. However, increased reliance on imported animal products also reduces rural employment and income earning opportunities for Chinese livestock farmers, which have been found to contribute importantly to resolving the "farm" problem.⁹²

Second, risks could be diversified through bilateral partnerships and foreign land deals as well as vertical integration or broader strategic investments in agriculture where there is still substantial potential for maize land expansion. The first two arrangements provide more direct control over the concerned food trades. However, such arrangements, especially land purchases/leasing, must also be responsive to the infrastructure needs of the hosting country and communities, maximize employment opportunities for the local population, work under governance structures that represent civil society, and minimize environmental externalities to be socially and politically viable and sustainable (Box 7). They could further be complemented with

⁸⁹ Rice remains thinly traded in the international market (only 6–7 percent of global production), while 10–12 percent of global maize production is exported.

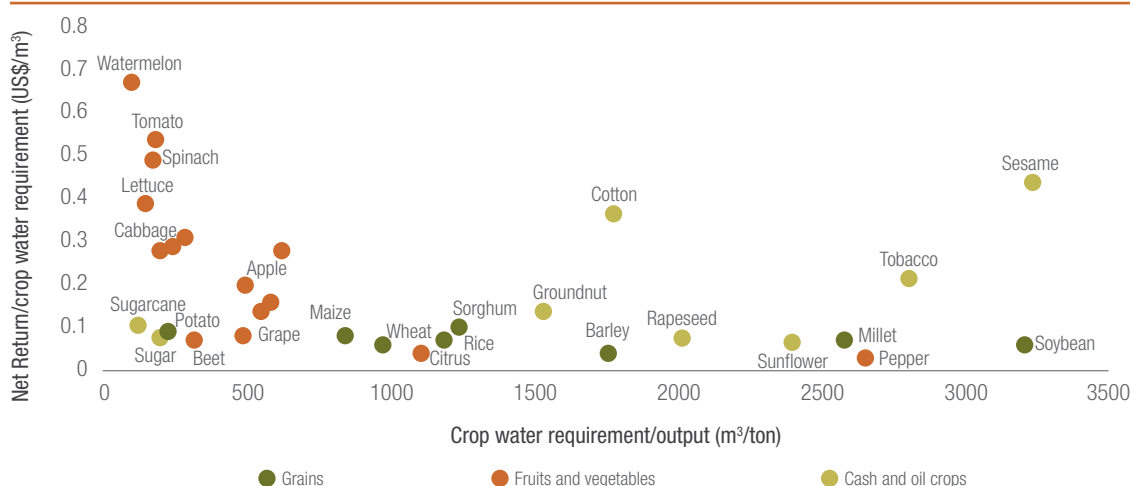
⁹⁰ Zhou et al. (2008).

⁹¹ Zhang and Hu (2011).

⁹² Ma et al. (2006). The CHINAGRO model II 2005–2030 simulations highlight the critical contribution of livestock production to stemming the rising divide between farm and nonfarm incomes (Keyzer and van Veen, 2010).

FIGURE 15

GRAINS (ESPECIALLY SOYBEANS) HAVE MUCH HIGHER CROP WATER REQUIREMENTS THAN FRUITS AND VEGETABLES AND MUCH LOWER NET RETURN; CASH CROPS AND OIL SEEDS ARE IN BETWEEN



Source: Liu, Zehnder and Yang (2007).

Note: crop water requirement refers to crop evapo-transpiration accumulated over the growing period of the respective crop (Chen et al., 1995). The water requirement for rice includes evapo-transpiration and percolation. Net return refers to the difference between total revenue and material costs; labor cost is not included. Yield and price data for grains are based on 1999–2001 averages from the National Bureau of Statistics and FAOSTAT for other crops.

BOX 7

OPPORTUNITIES AND CHALLENGES OF FARMING ABROAD – EMERGING EXPERIENCES FROM LATIN AMERICA

Fisher and Shah (2010) estimate that there is globally still about 83.3 million ha uncultivated non-forested land available with potential for maize production and 82.8 million ha for soybean production in areas with less than 25 persons/km² and at less than 6 hours from a market. This corresponds to about half the currently cultivated maize and 90 percent of the currently cultivated soybean area. Together, Argentina and Brazil alone have the potential to add 20 million ha to their current maize area. They provide the most immediate potential for area expansion. Farmers are familiar with the production of maize and yields are already high (6.5 and 4.1 ton/ha respectively). Several African nations also have substantial potential for rainfed maize production (Angola, Tanzania, Zambia), though yields are low and access to infrastructure is often a problem (e.g. Ethiopia). With 22 and 10 million ha of uncultivated non-protected area suitable for rainfed soybean production, Brazil and Argentina also offer the most immediate potential for area expansion in soybeans, with much of the remainder situated in Africa, either in countries where it is already produced but yields are low, or in countries with potential but little current experience (e.g. Sudan, Democratic Republic of Congo, Mozambique, etc.).

Despite the potential, Chinese purchases of vast tracts of land in Argentina and Brazil are increasingly making officials nervous, as related in several media articles such as the 27 May, 2011, New York Times article “China’s Farming Pursuits Make Brazil Uneasy”. As a result, Brazil’s attorney general reinterpreted a 1971 law in August 2010, making it significantly harder for foreigners to buy land in Brazil and Argentina’s president followed suit in April 2011, submitting a law to Congress limiting the size and concentration of rural land foreigners could own. In response, the focus is increasingly on leasing land as well as production agreements. In April 2011, Chongqing Grains signed for example a \$2.5 billion agreement to produce soybeans in the Brazilian state of Bahia. Useful guidelines for host countries and investing countries, and for investing companies and for the local populations where the investments are taking place, are provided in Deininger and Byerlee (2011).

Source: Fischer and Shah (2010); Deininger and Byerlee (2011); Barrionuevo (2011).

large scale and widespread investment in agriculture through bilateral development assistance and foreign diplomacy, especially in Africa, but also in neighboring countries with untapped potential. In a similar vein, given the interconnectedness of the world's food problems, China could usefully and dramatically increase its support to international agricultural research agencies such as those of the Consultative Group on International Agricultural Research (CGIAR), in line with its emerging international responsibilities. Support to raising agricultural productivity elsewhere has the added advantage that it indirectly also fosters world food trade, which benefits all. Government to government trading partnerships on the other hand remain imperfect substitutes for the trust building and better international coordination needed to foster world food trade.

Third, from China's perspective, the reliability of world markets is largely endogenous, in that it results from coordination (or lack thereof) among its major players, of which China is one. The typical response to commodity price shocks has been for exporters to impose export restrictions, while importers lower import tariffs. These actions have the effect of boosting world prices higher than would have resulted from the initial shock only, while often failing to meaningfully protect domestic populations from the initial price shock⁹³ (although China has been quite successful in this regard in 2008).⁹⁴ These restrictive trade practices during a commodity price shock represent a classic collective action problem. One country refraining from this type of insulation faces greater shocks than would apply if

countries collectively refrained from intervening. This suggests that the successive food price shocks of the late 2000s should be enough to motivate WTO members to negotiate a collective agreement to limit the extent of price-insulating policies. The opening up of importers' markets comes indeed with a mutual obligation for exporters to keep their exports flowing, also during times of (perceived) declines in global supplies.

As a 10-year member of the WTO, and the second-largest economy in the world, this presents an opportunity for China to exert a positive influence on global economic governance. In a similar vein, increased transparency over global grain stocks would further reduce price volatility caused by speculative moves based on ill-informed perceptions about global supplies.⁹⁵ China's support to greater grain stock transparency agreed to during the June 2011 G20 meeting of the ministers of agriculture in Deauville, France, is a first step in this direction. Overall, taking the lead on increased coordination and trust building represents the first best plan of action for China to enable greater reliance on feed grain imports. It would yield the most durable results.

Continue providing income security to address persistent pockets of food insecurity and forcefully tackle micro-nutrient deficiency. Despite remarkable success in securing national supplies, massive reduction in the incidence, depth and severity of poverty, and successful domestic food market liberalization, a sizeable number of people is still food insecure.⁹⁶ While many of them

⁹³ Martin and Anderson (2011) estimate that about 45% of the price spike in rice markets in 2006–2008 was owed to restrictive trade practices, and 30% of the spike in wheat markets. These effects are large.

⁹⁴ Fang (2010).

⁹⁵ Slayton (2009).

⁹⁶ According to the official statistics, 36 million people were still living below 1196 Yuan per year or US\$0.57/day. At such low levels of income, people are still struggling to meet their daily minimum needs, including this of food.

still live concentrated in western provinces and the mountainous and ethnic minority areas, a substantial share lives now also dispersed across villages in non-mountainous, non-minority areas.⁹⁷ And new issues of micro-nutrient deficiency such as anemia have emerged following the depopulation of rural areas and the ensuing consolidation of primary school children in boarding schools.⁹⁸

The need to move beyond securing national supplies in addressing China's food problem to also incorporate household income and access to food has long been recognized. It has given rise to a series of poor area development programs starting as early as the mid 1980s.⁹⁹ In recognition of the wider geographic dispersion of the poor, these have more recently been supplemented by a rapid increase in targeted income transfers (from 2.5 billion RMB rural dibao expenditures in 2005 covering 8.25 million beneficiaries at a rate of 76 RMB/person/month, to 39 billion RMB in 2009 reaching 47.6 million people at a rate of 101 RMB/person/month). And anemia incidence among primary school boarders has now also attracted attention at the highest level.¹⁰⁰

Overall, ensuring access to food in the remaining pockets of hunger requires increasing employment opportunities for the unskilled poor and increasing the return to their labor. This

does not only reduce poverty, but also contributes to economic growth. The migration pathway offers some opportunities here, though many of the poorer are also less able to migrate, given lower education levels, and limited access to information and lack of formal and informal labor recruitment networks. The expenses related to movement and labor search costs and higher costs of health and education for migrants' children in the cities pose further challenges. Development of small and medium towns can provide more accessible off-farm employment opportunities for the poor closer to home.¹⁰¹ Promoting agricultural development also holds important opportunities.¹⁰² Overall, it would require making the existing poor area programs more effective in the range of employment opportunities they produce. Continuation of the ongoing expansion of social protection system into the rural areas is further desired, especially for those unable to work, though the need for assessing its effectiveness in reducing poverty presents itself, especially since the rapid expansion of the rural dibao program over the past couple of years.

Finally, initial policy responses to reduce anemia incidence among primary school boarders in Shaanxi and Ningxia by providing every student with one egg a day (or one glass of milk) are unlikely to suffice to overcome micro-nutrient deficiencies in general, and iron deficiency anemia in particular. They

⁹⁷ World Bank (2009) estimated their share at more than 50%.

⁹⁸ Luo et al. (2012). Anemia incidence levels of 38 percent were recorded among primary school boarders in 8 of the poorest counties in Shaanxi. Prolonged iron deficiency impairs hemoglobin production, limiting the amount of oxygen that red blood cells carry. It leads to lethargy, fatigue, poor attention and prolonged physical impairment, negatively affecting educational outcomes such as grades, attendance and attainment.

⁹⁹ See Ravallion and Chen (2005), Chen, Mu, and Ravallion (2009), Christiaensen, Bhattamishra, Pan and Wang (2009), and Park and Wang (2010) for a description and assessment of different poor area development programs in China over the 1985–2005 period.

¹⁰⁰ http://reap.stanford.edu/research/teachers_parents_and_students_teaming_up_to_learn_about_overcoming_anemia/

¹⁰¹ Currently, more than 60 percent of rural migrant laborers work in medium-large cities at prefecture level or above (World Bank, 2009).

¹⁰² Christiaensen, Pan and Wang (2010).

don't contain iron. A series of randomized experiments of different treatment packages and sensitization campaigns (e.g. letters to the parents/innovative curricula) in collaboration with the respective provincial governments are currently underway to identify more effective interventions. Better nutritional outcomes improve educational performance¹⁰³ and can also reduce dropout rates from high school in rural China, which are much higher than in urban areas. Given high returns to higher education, this will become increasingly important to enable the rural population to increase their incomes and stem the rising rural-urban divide.

4.2 RATIONALIZE FACTOR MARKETS AND USE INSTITUTIONAL INNOVATIONS

4.2.1 Rationalize Factor Markets to Facilitate Farm Consolidation

Rationalization of factor markets (land, labor and capital) will facilitate land consolidation and the creation of commercially viable smallholder agriculture. To remain competitive, domestically and internationally, Chinese farms must grow in size, as has also been observed historically in other high income countries (Box 8). Rising total factor productivity in agriculture, even though historically high and still inordinately important for the future (see point 4.3), is unlikely to suffice to close the income gap with non-agriculture.¹⁰⁴ The scope for a more rapid increase in food prices is also limited.¹⁰⁵ China's WTO commit-

ments further limit the scope for raising farm incomes through increased protection at the border, though some room remains.

Creating a commercially viable smallholder agriculture will especially entail institutional innovations in the land, labor and rural capital markets to facilitate farm consolidation and an orderly transition of labor out of agriculture as well as an urbanization process that avoids urban overconcentration and facilitates secondary town development to productively absorb a significant part of this labor in a buoyant rural economy, more like in Thailand and Taiwan (China) than in the Philippines and South Korea respectively.¹⁰⁶ The balancing act is to accommodate land consolidation and labor movements so as to remain self sufficient in the core staples (rice and wheat) at internationally competitive prices (the food problem), while at the same time maintaining commercially viable livelihoods for a sufficiently large group of smallholder farmers both through full and part time farming. This will be critical to stem the growing rural-urban divide and maximize poverty reduction (the farm income problem). Indeed, given the current initial conditions, by 2030, China's farming landscape will still be largely dominated by smaller holdings, by any international standard (Box 4).

Fostering land rental is the most practical way forward in the near and medium term, while reforms in private land use rights and their marketability proceed; voluntary exchange platforms can also help. As land can currently not be bought or sold, land consolidation must happen through

¹⁰³ Test scores among those provided with multivitamin with mineral supplements improved for example by 0.4 standard deviations (akin to moving from a "C+" to a "B" in the American grading system).

¹⁰⁴ TFP has been growing at 2 per cent on average over the past two and a half decades, which was at least as fast as daily wage growth for male workers until the mid 2000s. Since then, rural daily wage growth for male workers has picked up substantially, growing on average at 9.1 percent between 2004 and 2007 (Zhang and Yang, 2011).

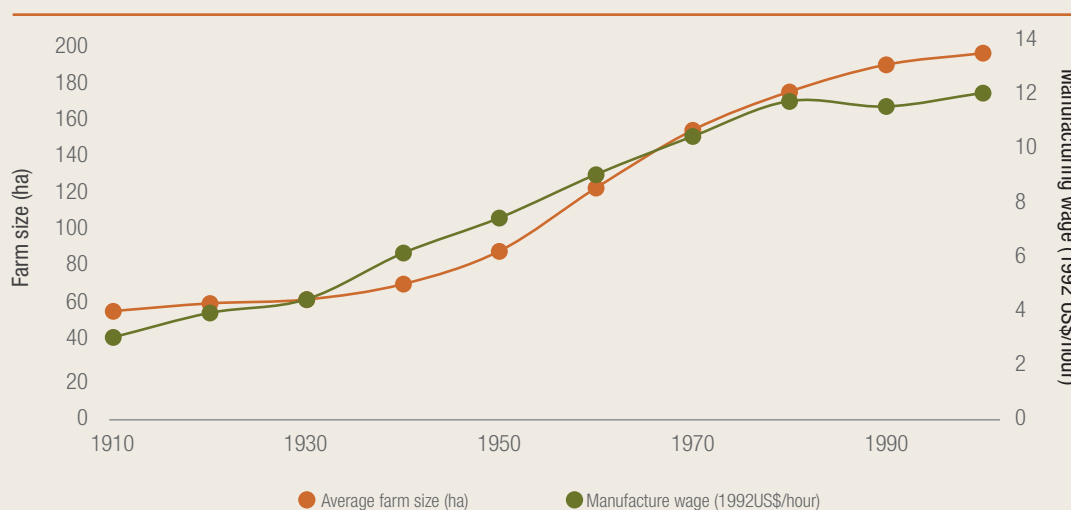
¹⁰⁵ Between 2000 and 2010 the domestic grain food price index already rose by 73 percent. Increasing domestic food prices faster is unlikely and would not be politically palatable.

¹⁰⁶ Otsuka (2007) and Christiaensen (2007).

BOX 8

FARM SIZE RISES IN LINE WITH NON-AGRICULTURAL WAGES – INSIGHTS FROM THE US EXPERIENCE

A close relation has historically been observed between the evolution of nonagricultural wages and the size of farms. As rural nonagricultural wages rise, farm operators seek ways to attain incomes comparable to what they can attain in other sectors. This usually implies substitution of capital for labor and an increase of farm size in line with nonagricultural wage rates, both to capture economies of scale arising from the indivisibility of inputs, but also to generate sufficient volume to yield incomes comparable with those attained outside the sector. The co-movement of non-agricultural wages and farm size observed in the United States for most of the 20th century is indeed striking in this regard.



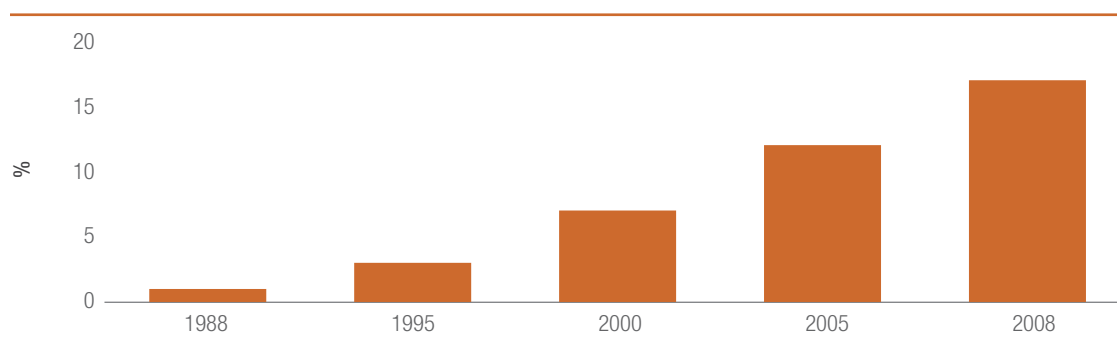
Source: Based on Gardner (2002)

Similarly, the pressure on land consolidation emanating from intersectoral labor competition in China was strikingly illustrated by the numerical example discussed in Box 3. It showed that to generate a similar increase in income from rice farming as the 2003–2008 observed increase in rural household incomes, average farm size would have had to increase six times in 5 years (or 8 times when excluding the increase in subsidy), implying that one in six farmers would have to give up farming each year. These calculations already take into account a 52 percentage point rise in the grain price index between 2003 and 2008. And while the upward trend in grain prices has continued into 2011, rising domestic grain prices much faster as a way to increase incomes from farming is unlikely and would not be politically palatable, even though rice prices remain well below the world market price (though not those for wheat and soybeans).

land rental markets. Even if land sales were already possible, they are likely slower and unlikely to function competitively as a means to facilitate a swift and steady land reallocation across households because of imperfections in credit markets. Land rental markets are

the practical way forward in the near and medium term for achieving an efficient land allocation across households, while reforms in private land use rights and their marketability proceed.¹⁰⁷ The trend in land rental, by aging farmers or farmers who have migrated to

¹⁰⁷ As highlighted by Kevane (1996), if at least one of the three factor markets (labor, land sales, or land rental) functions competitively, an efficient allocation of resources can be achieved under the assumption of constant returns to scale. In the near to medium term this is most likely to be the case for the land rental market.

FIGURE 16**THE SHARE OF AGRICULTURAL LAND BEING RENTED IS RISING RAPIDLY**

Source: Huang and Rozelle (2011).

cities, is indeed strongly positive, from 7 percent of agricultural land in 2000, to 19 percent in 2008 (Figure 16). In the more developed eastern provinces such as Zhejiang, it even reaches as high as 40%. There are also reports of complete village reorganizations into large, company run farms whereby remaining villagers give up their land in return for housing (and lifetime compensation) at the urban fringe. The scale of such consolidation initiatives is so far unknown, as are the long term welfare effects for the farmers involved. Overall, lingering concerns about tenure security,¹⁰⁸ uncertainties related to land registration and substantial coordination costs continue to hamper consolidation. These costs are even higher in mountainous areas, where plots are smaller and more scattered.

Better tenure security is needed to deepen the rural land rental market. This requires a number of specific land management related steps. First, existing land use rights need to be secured by expanding the renewability and duration of existing contracts, improving documentation, and enhancing awareness of existing rights. Second, the registration of farmland needs to be gradually scaled up, with international experience pointing to

the benefits of combining this under a single agency. Recent evidence underscores the singularity with which land certification can increase productivity (by up to 30 percent), not so much through increased investment, but rather by fostering urban migration and freeing up land for rental by those specializing in farming.¹⁰⁹ Third, more transparency and bottom up accountability in the governance structures of the rural collective will be needed to reduce questionable land readjustments within the collective. Or, as the contradictions between collective practices and the trend towards private land use rights, permanent tenure security, and the marketability of land use rights are growing, China could also begin the gradual transition from collective ownership to state ownership of rural land instead of seeking to narrow the governance deficit within the collective. This could be a way to simplify China's land tenure framework, overcome its inherent contradictions and gradually transition to a unified land market.

Government assisted voluntary exchange platforms could further assist both in plot and farm consolidation. Land consolidation programs, which aim to consolidate spatially dispersed fragments of farmland to form

¹⁰⁸ Kimura, Otsuka, Sonobe and Rozelle (2011).

¹⁰⁹ Deininger, Jin and Xia (2011).

larger and more cohesive plots and farm holdings, are not new to China. They have been installed since the 1980s. But, implementation by local governments has often been slow, as the consolidation process typically involves many households, which raises transaction costs.¹¹⁰ Government initiated land consolidation programs have been successfully applied elsewhere as well, with a rigorous recent evaluation of Japan's Farmland Improvement Projects (FIP) showing clear improvements in production conditions due to plot consolidation, enabling mechanization through machinery services in the plains, while encouraging farmers' exit in steeper communities by promoting elderly farmer retirement.¹¹¹

Enhancing rural social protection will also help free up land for renting.

Cultivated land continues to provide an informal safety net against unemployment, sickness and old age. Improving land tenure security must thus go hand in hand with scaling up rural social protection to facilitate land rentals and land consolidation. Important steps in this direction are anticipated under the 12th 5-year plan, including the expansion of low income welfare payments, rural health insurance, and rural pensions. Success in social insurance will help in freeing up land and facilitating land consolidation, as will improved labor mobility.

Removal of remaining barriers to labor mobility combined with small town development further helps agricultural labor sort itself according to its comparative advantage. Despite widespread rural-urban

migration, especially circular migration, and continuous relaxations of the household registration (hukou) system, further reforms of the hukou system are desirable to free up land for farm consolidation and help farmers sort themselves according to their comparative advantage.¹¹² When accompanied with small and medium town development, part time farming could also be promoted, especially in mountainous areas where opportunities for land consolidation are more limited. Such a strategy can build on the "leaving the village without leaving the country side" policy of the early 1990s, which proved hugely successful in generating rural nonfarm employment nearby through the development of small towns in coastal areas.¹¹³

While these coastal towns often benefited from access to export markets or spillovers from growing cities, the conditions are much more favorable now to absorb the next wave of urban migrants by developing small and medium towns in China's interior provinces. Congestion increasingly plagues the coastal metropolises, coastal provinces are climbing up the skill and value chain, and labor intensive industries are increasingly moving inward. Central support of such a strategy is consistent with the objective of reducing the regional and rural-urban divide. It requires increased investment in rural education and improved rural transportation to link towns with their rural hinterlands and to link farmers with their off-farm jobs in rural towns, often in related agro industries. Consistent with the gradual reform approach, the next reform phase of the hukou system should focus on facilitating migration to these small and medium towns (Box 9).

¹¹⁰ Tan, Heerink, and Qu (2006).

¹¹¹ Arimoto (2011).

¹¹² Examining the impact of rural-to-urban migration on rural poverty and inequality in a mountainous area of Hubei Province using data of a 2002 household survey Zhu and Luo (2010) find that 1) farmers with higher expected return in agricultural activities and/or in local nonfarm activities choose to remain in the countryside, while those with higher expected return in urban nonfarm sectors migrate; 2) households with binding land constraints are more likely to migrate; 3) poorer households benefit disproportionately from migration.

¹¹³ Gale and Dai (2002).

PART-TIME FARMING – AN IMPORTANT PATH OUT OF POVERTY IN LATIN AMERICA

In addition to modernizing agriculture on smallholder farms, pluri-activity or part time farming has also been a successful, though largely ignored path out of poverty for many farmers in Latin America. Part time farming is already the reality on many of today's farms in China, given the large amount of circular migration. It is likely to hold most promise in mountainous areas where transaction costs in accessing food markets are higher and shadow prices (for self sufficient households) and purchase prices (for net buying households) are thus more likely to exceed those for net sellers. In such an environment, part time farming can be economical even when market prices are too low for net sellers to be competitive. As farming in part-time farming households is more often in the hands of women and elders than of adult men, access to labor saving technology is even more important. This further underscores the importance of machine rentals in overcoming indivisibility of machine inputs (see below). Technologies should also not be excessively sensitive to discontinuities in the presence of adult workers, so that they can flexibly respond to off-farm employment opportunities.

Source: de Janvry and Sadoulet, 2000.

As farms consolidate, access to credit becomes more important, though machine rental markets can already go a long way in overcoming credit constraints. While remittances and informal channels largely sufficed to finance modern inputs in the past, mechanization of grain cultivation will require greater access to bank capital in rural areas. According to the China Bank Regulatory Commission finance service map database, only 31.4 percent of rural households had ever borrowed from banks at the end of 2009, and only 30.1 percent of micro- and small-enterprises. Most agricultural loans (85 percent) come from Rural Credit Cooperatives (RCCs), instead of banks. A comprehensive regulatory and supervisory framework for rural and micro-finance institutions should be developed, with the government focusing on creating the infrastructure and market environment for rural finance instead of direct public provision of financial services. Competition should be advanced, for

example through the formalization of informal lenders or cooperative financial institutions rooted in village-level bottom-up organizations.

But credit market imperfections can also be mitigated through institutional innovations such as machine rentals. The use of machine renting has historically been practiced in many Asian countries to capture economies of scale¹¹⁴ and is also on the rise in China. If properly coordinated, machine rentals provide a practical and convenient way to substitute capital for labor, also for part time farmers, who are often most in need of labor saving technology. It helps overcome the indivisibility of machine inputs when credit markets are absent or imperfect. The government has rightly been supporting the development of such machine service delivery organizations through machinery subsidization, though support through providing credit provision, perhaps based on leasing, might be more effective.¹¹⁵ The development

¹¹⁴ Takahashi and Otsuka (2009).

¹¹⁵ Machinery subsidies are available to individual farmers, so-called specialized households and agricultural machine service delivery organizations. Starting with CNY 480 million in 2005, machinery subsidies rose to CNY 17.8 billion in 2010. The subsidy typically compensates 20–30 percent of the purchase price and was initially targeted at the mechanization of wheat harvesting and rice planting, with trials in 2007 to expand to the mechanization of maize harvesting.

of better models to support mechanization deserves further investigation.

Together, machine rental and land consolidation can go a long way to help smallholders remain intersectorally and internationally competitive, either as part time farmers (mountainous areas) or as commercial smallholders. This will be critical to help China's agriculture simultaneously resolve its farm and food problem. Complemented with the smart use of agricultural subsidies in eco-compensation schemes, smallholders could further become a powerful force of natural resource restoration and conservation, addressing agriculture's field problems (see also section 4.4).

4.2.2 Make Producer Cooperatives Work More Effectively For Smallholders

Farmer cooperatives provide a natural institutional route to enable smallholders to capture the rising emerging economies of scale in the processing and marketing of high value agricultural products. The need for volume, consistency and quality in processing and marketing high value agricultural products induces vertical integration of the supply chains. This happens often at the expense of smallholders. Against this background, producer cooperatives are a natural institutional route to enable smallholders to reduce transaction costs in ensuring volume, consistency and quality and thus a potentially potent vehicle to link smallholders to the dynamic high value markets, which provide an important opportunity to address the “farm income” problem. Tightened control over the production process also increases food safety.¹¹⁶ This is

critical in accessing and expanding both domestic and export markets. The concentration of animals in larger production units further facilitates animal waste management, including through biogas digesters, thereby reducing nonpoint source pollution and methane emissions.¹¹⁷ This mitigates agriculture's field problem. Following the enactment of the China Farmers Professional Co-operative Law (FPCL) in 2007, there has been a rapid expansion of farmers' cooperatives. By the end of September 2008, there were 79,600 registered farmers co-operatives, with a membership of 1.08 million, 96 per cent of which were farmers.

But there are rising concerns that the emerging cooperative structures do not enable smallholders to capture the full benefits from high value products. Two types of cooperatives have emerged, the farmer-led cooperatives and the “Company + Household” cooperatives. In the latter model, shares are controlled by a leading agribusiness and other key shareholders (e.g. government officials) with farmers as participating members. Farmer-led cooperatives on the other hand are usually organized in a blockholder structure. They are controlled and owned by one or more large, wealthy households with smallholders participating as peripheral members. Voting rights and profits are usually proportional to the capital brought in. These are the two structures increasingly observed in intensive animal husbandry. The extent to which they are starting to permeate the fruit and vegetable, and even the grain sector, is unclear. Among the two types, the C+H structures are often preferred by local government, and supported through tax breaks, subsidized loans and the provision of land.

¹¹⁶ In effect, downstream agro-processors (e.g. dairy firms) are increasingly procuring only from larger production entities, precisely for this reason.

¹¹⁷ Methane and nitrous oxides from soils (from inorganic and organic fertilizer application) are the two potent non carbon dioxide greenhouse gases (GHG).

While these new cooperative structures provide smallholders with access to the high value markets, smallholder farmers forego in effect most of the benefits. They are mostly excluded from the decision making process in the cooperatives and miss out on the lion's share of the profits and the government's support, which is capitalized in the assets of the core members. Also, the monopsonic power of the downstream agro-processing companies continues to persist. In conclusion, despite their important potential in mitigating the "farm problem" and reducing the rural-urban divide, cooperatives are currently not yet living up fully to that promise. As these two types of cooperatives are rapidly becoming a part of China's agricultural landscape, these developments need to be monitored more closely and steps should be taken to better protect the interests of minority shareholder, while the formation of member-owned and controlled farmer co-operatives should be encouraged.

4.3 CONTINUE STRENGTHENING THE PROVISION OF (RURAL) PUBLIC GOODS

4.3.1 Invest More and Better in Agricultural Technology

Continue the increase in investment in agricultural R&D to foster long term productivity growth and retain smallholder competitiveness. Given constraints on expanding water and modern input use and institutional limits on the speed of land consolidation, growth in total factor productivity (TFP) will be key to keep smallholder farmers competitive and raise their incomes. That China managed to maintain an average agricultural TFP growth of about 2 percent over the past decades, even in the face of set-backs during the course of this period,

provides hope in this regard. It underscores the determination of China's policymakers and the resilience of the system to respond.

Particularly, following the important fall back in the research system's performance by the late 1980s, a nationwide reform of the research system was launched to increase its productivity. Funds were shifted from institutional support to a more competitive distribution of research grants and applied research institutes were encouraged to rely more on the commercialization of their own research. In addition, following years of stagnant growth during the 1990s, government-sponsored R&D increased by 5.5 percent annually between 1995 and 2000, accelerating to about 10 percent between 2001 and 2007, on par with national growth. Between 2009 and 2010, the government was expected to further double its spending on agricultural R&D. During the past decade, the increases in investment in agricultural research and development have been the most rapid of any large nation.

Nonetheless, much more investment in agricultural R&D will be needed. Despite its rapid growth, at 0.5–0.6 percent of agricultural GDP in 2007, China's agricultural R&D spending still lags behind this of most developed countries and the world's average of 1 percent. It is estimated that to maintain the 1995–2005 yield growth investments in agricultural R&D will have to increase by 15 percent annually between 2005 and 2020 (i.e. by 43 billion Yuan in 2005 prices or US\$5.25 billion).¹¹⁸

China is increasingly betting on agricultural biotechnology, including GM corn, to promote TFP growth in the future. In 2008, it supplemented its ongoing research on agricultural biotechnology,

¹¹⁸ Chen and Zhang (2010).

which involved more than 20 crops and livestock, fishery and forestry products, with the 26 billion Yuan (US\$ 3.8 billion) 2009–2020 “Special Program” focused on supporting research on and the development of 5 genetically modified staple crops (rice, wheat, maize, cotton and soybeans) and 3 types of livestock commodities (hog, cattle and sheep). The focus is thus on crops for the domestic market in which it misses a natural comparative advantage. China is also investing heavily in bio-safety management institutions to monitor and supervise the new technologies and enable the issuance of commercialization permits.

China was one of the first countries to grow GM crops commercially,¹¹⁹ and now ranks among the top six countries in terms of area of land used to cultivate GM crops.¹²⁰ The most prevalent GM crop is cotton (*Bt*). Since being approved for commercialization in China in 1997, transgenic species of cotton now account for over 70% (3.9 million ha) of all land planted with cotton.¹²¹ Of China’s major grain crops, GM rice and maize have been approved for commercialization,¹²² consistent with heightened concerns about maintaining self sufficiency in these two staples. They are not being adopted on a large scale yet. GM soybeans also hold promise. Biotech soy is one of the world’s most widely planted

transgenic crops, having been successfully adopted in the US and most Latin American countries. China is one of the world’s largest consumers of GM soy, though it has not been approved for domestic, commercial-scale production yet.¹²³ According to officials, China could be a leader in GMO foods, cloning, large-scale transgenic technologies and new breed promotion by 2020.

But genetic engineering alone will not suffice and potential shifts in consumers’ attitudes towards GMO foods are lurking in the background.¹²⁴ While consumer attitudes towards GM crops have so far played little part in shaping the approach towards bio-safety regulation, public information and understanding of GM crops has remained limited. How broader awareness about GM crops would affect consumer acceptance is an important development to be watched. Against this background, being an animal feed, GM corn may have more potential in the short run.¹²⁵

Much will also need to be gained from investments in agricultural ecology and the development and widespread adoption of more sustainable agronomic practices. Such a shift in emphasis is consistent with the functional shift in agriculture as China modernizes, from sole pre-occupation with the food problem to also addressing the

¹¹⁹ Huang J.K. et al (2004).

¹²⁰ Nábrádi and Popp (2011).

¹²¹ James (2011); NBS (2011).

¹²² Chen M. et al (2011). GM tomatoes and papaya have also been approved for commercialization, though are grown on a relatively small area (see Pray et al, 2011; Huang J.K. et al 2002).

¹²³ Nábrádi and Popp (2011); Xia L.Q. et al (2011).

¹²⁴ The issuance of bio-safety certificates for Bt rice production in 2009, with an estimated 10 million rice growing households (or 440 million people) potentially benefiting from the technology, provoked much debate in China, despite its enormous potential.

¹²⁵ Recent unofficial reports about a potential push forward within the next 5 to 10 years of GM maize to respond to the rapidly rising demand pressures are revealing in this regard. Concerns from various sides that GM crop research, regulations, and later-stage business operations may not yet be mature to commercialize are mentioned as the key reasons for a potentially delay in the commercialization of GM rice and wheat beyond the next 5 to 10 years. As animal feed GM maize is less likely to face the same resistance (Economic Observer via GM Watch, Jiang Yunzhang, October 12, 2011).

farm and field problems. Since the late 1990s, agricultural R&D has begun to pay attention to sustainable development (the field problem) through a series of core environmental initiatives,¹²⁶ including a national program on balanced fertilization and integrated pest management and a number of initiatives supporting research on the impacts of climate change (see section 4.6). Given water scarcity, widespread non-point source pollution and important economic gains from lower input use, these areas of investments will need to be ramped up.

Key technologies include zero or low tillage in grain production and the expansion of green belts (to 10–100 meters) along waterways to capture run-off before it enters surface waters, especially in areas where intensified livestock is concentrated (East Region) and over fertilization of crops is rampant (Central, West and South West Regions). Slower releasing chemical fertilizers can further help combat overuse of fertilizer among migrant farmers absent at the optimal moments for fertilizer application. Meteorology and soil based precision farming and improved water management through advanced technologies¹²⁷ and evapo-transpiration monitoring (ET) can help in addressing water scarcity, not least in the northern plains, where water scarcity is most dire (see further section 4.5). Solar power and biogas from agricultural residuals and animal waste can help save energy. Continued implementation of the National Land Conversion Program of sloped farm land into forest, shrub or grassland will help fight erosion and land degradation, an important unfinished challenge, especially in the western regions.

Public funding of extension agents becomes more important in shifting cultivation to more sustainable practices.

Sustainable agronomic practices often require upfront investments while their effects often materialize only after a couple of seasons. This contrasts sharply with the more immediate effects of the modern input packages (hybrid seeds, fertilizer, irrigation), which were often also adopted despite malfunctioning agricultural service systems. Transferring sustainable agronomic practices to farmers (including reduced fertilizer use) usually requires substantial face-to-face time between farmers and agricultural extension agents. This can be achieved by strengthening the ongoing reversal to institutional funding of extension agents. After the 1988 reforms, which shifted the publicly funded extension system to a fee for service system, extension agents were found to spend only 81 days per year providing agricultural services, with those partially funded by the government spending only 27 days.¹²⁸ In addition and more broadly, devolving control over part of the public extension funds to the producers or producer cooperatives, who could subsequently hire extension agents themselves, could further make extension services more responsive to the farmers' needs and thereby making them more effective.

Better alignment of research with the ongoing structural change of the sector (from crop to non-crop) is recommended. Research allocations among agricultural subsectors have not kept up with the evolving restructuring of agriculture. Grain security has been the key objective for public agricultural R&D, with about half of public

¹²⁶ Some of the key initiatives include the Grain for Green program, the South-North Water Transfer project, the Three North Shelter-Belt program, and Ecological Programs.

¹²⁷ With only about 800,000 ha, or about 1.5 percent of its irrigated land, under modern irrigation, China still has very low adoption rates of modern irrigation technology such as sprinkler irrigation, drip irrigation and micro irrigation (Chen and Zhang, 2010).

¹²⁸ Hu et al. (2009).

agricultural R&D going to crops.¹²⁹ This has remained virtually unchanged over the past two decades, despite the rapidly rising importance of the non-grain sectors. The gap in public investment in the non-grain sectors (especially animal husbandry and food processing) has been partly picked up by the private sectors, whose investments have increased dramatically, from less than 2 percent of total public agricultural R&D being private in 1999 to 22 percent being private in 2006. The latter is still well below the 50 percent of total public R&D expenditure obtained in most developed nations. But, to enable smallholders to benefit maximally from rising demand in high value product production, public research investments in vegetables, livestock, and fish should also be increased. More attention should also go to the development of smaller labor saving tools and equipment that are also accessible to part-time and female farmers.

A better mix of basic and applied research and a series of institutional reforms can further increase efficiency of research spending. First, despite efforts to encourage basic research, most spending still goes to applied research (24 percent in 2007) and development (70 percent in 2007), leaving only 6 percent for basic research. By comparison, the United States, France, Japan, and South Korea spend between 12 (South Korea) and 27 percent (France) on basic research. This partly explains the limited innovative capacity of China's agricultural R&D system. Despite a rapid increase in patents, they are largely utility models or design patents, and not invention patents. Moreover, many

of China's agricultural scientific and technical advances are not adopted in practice (only 30–40 percent compared with 65–85 percent in developed countries). Excessive competition and decentralization of resources further lower research efficiency. Some of these tendencies might be remedied by promoting a select number of “elite” scientists and research groups. More emphasis should also be placed on proper monitoring and rigorous data driven evaluation systems to provide timely feedback about the success and failures of the myriad of research and technology initiatives being launched.

4.3.2 Target Investment in Rural Education and Infrastructure

In addition to agricultural R&D, increasing investment in infrastructure and rural education has also high payoffs in mitigating both the food and farm problems.

Extensive research on the returns to public investment in China (and a series of other countries) carried out by the International Food Policy Research (IFRPI)¹³⁰ confirms the critical importance of agricultural R&D for increasing agricultural GDP (the “food problem”). It yielded the highest return per Yuan of public investment and closely tracked the returns to rural education in reducing poverty. Public investment in rural education also contributed most to increasing rural incomes, reducing the rural-urban divide (the “farm problem”). In this, it was closely followed by rural roads, which were not only very effective in increasing rural incomes, but also proved to yield higher returns than investment in highways.¹³¹ The marginal returns to low grade roads (most of which are rural) were estimated

¹²⁹ During 1986–95, about 49 percent of public agricultural R&D in China went to the crop sector, 10 percent to forestry, 12 percent to livestock, 7 percent to fisheries, 5 percent to agricultural services, 9 percent to water conservation and 6 percent to primary food processing. This division of funds remained virtually unchanged, with 48 percent going to the crop sector, 9 percent to forestry, 6 percent to livestock and 5 percent to fisheries during 2001–2007.

¹³⁰ Fan, Zhang and Zhang (2004).

¹³¹ Fan and Chan-Kang (2008).

to be higher than those to high grade roads across the board, i.e. in increasing overall GDP, as well as urban and rural non-farm incomes, with the returns to low grade roads in terms of rural non-farm income larger than those of urban GDP. Interestingly, low grade roads proved also more effective in reducing urban poverty than high grade roads.

Focus investments in rural infrastructure in lagging regions and combine them with cluster development. The IFPRI findings further suggest that the returns to rural education and rural roads are not only large (and larger than those in urban areas), they also highlight substantial differences across regions. When it comes to increasing rural incomes (including rural nonfarm), the returns were highest in the coastal regions. When it comes to reducing poverty and inequality, they were highest in the western regions. To be sure, these (marginal) return estimates are calibrated on data from the early 2000s, and China has substantially increased its public investments in western provinces and rural areas under the “Go West” program (10th five year plan going from 2000–2005) and the “New Socialist Countryside” (11th five year plan). Since the mid 2000s, overall regional inequality has also come down slightly, hinting at a potential pay-off of these programs.

But, with labor costs rising rapidly along the coast and many previously inaccessible interior regions now better connected through the expanded road network, many rural off-farm opportunities are likely to open up, as businesses relocate inland following outsourcing by urban and coastal production centers. This increases the returns to rural roads and small town development in interior China and provides important opportunities for a buoyant rural economy. In this, the potential of

nurturing cluster development deserves special attention, following the example of cluster based production in the coastal areas to overcome a series of factor market constraints (e.g. capital market).¹³² For the most remote areas and fragile environments, the marginal returns to infrastructure investment may decline too quickly as costs rise rapidly, making outmigration and social protection measures the more viable options.

Foster investment in rural education through governance reforms and targeted transfers in lagging regions. In addition to raising investment in rural roads, China has also increased its attention on rural education. But, local governments still bear a large share of the burden to educate especially the children of migrant workers, who often stay behind with their grandparents, while their migrated parents work and pay taxes in the developed regions. Following fiscal decentralization, local expenditures are more tightly linked to local revenues, while local responsibilities for the provision of local public good services such as education, roads are remained at similar levels. As a result, poorer counties with a smaller tax base, see themselves unduly burdened. With incentives for local authorities biased towards reaching economic growth targets, inducing a preference for infrastructure investment as opposed to social spending with much more delayed pay-offs, spending on rural education in inland provinces suffers.

A disproportionately larger population to serve with less resources at hand, has resulted in substantially less spending per capita on education and health in inland than in coastal provinces—the difference estimated at a factor 1.5.¹³³ High boarding costs are indeed often cited as an important reason for early drop out of secondary school in poorer

¹³² Jiangqing and Zhang (2009).

¹³³ Yao (2009).

rural areas and prohibitive costs also prevent many rural children from continuing to college. Conditional cash transfers, similar to the Progressa program in Mexico (now Oportunidades) could be considered, with a recent trial in Northwest China also showing promising results.¹³⁴ It will further require more experimentation with governance reform, including for example the inclusion of social development indicators in cadres' performance contracts combined with an extension of their tenure to encourage greater attention to social outcomes.

4.3.3 Tackle Food Safety Issues More Effectively

Better education, consolidation of responsibilities among government agencies, separation of risk management and risk assessment, and shifting responsibility to the food industry would go a long way in improving China's food safety.¹³⁵ Despite enormous efforts of the government over the past decade in improving its food safety policies, regulations and institutions at all levels, frequent food safety scandals continue to damage public health and undermine consumer confidence in Chinese agricultural produce, at home and abroad. They affect especially livestock products and fruits and vegetables and prevent Chinese agriculture from benefiting fully of the employment and income generating opportunities that rising domestic and international demand for high value products presents.¹³⁶ Part of the problem is continued lack

of awareness of food safety issues among producers, consumers and the private sector. Such a lack of knowledge could be overcome by massive awareness campaigns and greater clarity about the legal and blacklisted food additives. But, the food safety challenges go well beyond a benign lack of understanding. They are mainly institutional.

In particular, the legal and regulatory framework remains incomplete and fragmented, with too many agencies involved in its implementation and enforcement. Inefficiencies are further compounded by a lack of interagency coordination and clarity about their respective roles and responsibilities.¹³⁷ A rigorous risk based monitoring and testing system remains missing, and the incentives and capacity in the private sector to embrace such a system remain too low. China's authorities have become acutely aware of these challenges, but have so far not managed to address them effectively. While food safety scandals are not unique to China—Belgium's dioxine crisis in 1999 following mixture of dioxine-contaminated animal fat in animal feed just being one of the more illustrious examples¹³⁸—tackling food safety issues forcefully poses an immediate and urgent agenda for China's agriculture, one befitting its ambitions of becoming a modern, harmonious and high income society.

This will require:

- An upgrading of the legal frameworks and regulations to cover the whole food

¹³⁴ A recent randomized trial of a conditional cash transfer program on a sample of 300 junior high school students in a nationally designated poor county in Northwest China showed a reduction in drop out by 60 %, from 13.3 % in the control group, to 5.3 % in the treatment group. The program was most effective for girls, younger students and the poorest performing pupils (Mo et al., 2011).

¹³⁵ World Bank (2008).

¹³⁶ Imported dairy products nearly quintupled in volume in 2009, the year after the melamine scandal. Foreign brands now account for half of all infant milk powder sold in China (New York Times, 2011).

¹³⁷ For example, the Commerce Ministry supervises pork slaughterhouses, but beef and poultry slaughterhouses fall under the Agriculture Ministry.

¹³⁸ Covaci et al. (2008). http://foodsafety.k-state.edu/articles/316/belgian_dioxin_crisis_risk_comm.pdf

production, processing and marketing systems. It should include the general principle that any deliberate adulteration of food products or negligent mis-handling of food that could endanger consumer health should be considered a criminal offense.

- A clarification and streamlining of the institutional structures that strengthens accountability at all levels. In this, provincial governments must take on significant responsibility for implementation—especially for monitoring and surveillance—under centrally mandated guidelines. Overall, it will require a long term commitment to open dialogue, transparency, and extensive training of relevant government officials.
- A focus of government input on food safety responsibilities that are inherently public, such as ensuring compliance with laws and regulations through a risk based monitoring and testing system, enhancing awareness, distributing good agricultural practice and planning infrastructure in consultation with the private sector.
- The promotion of private sector action through targeted support to enhance their capacity, as well increased incentives to hold the private sector liable for food safety.

4.4 SUPPORT RURAL INCOMES WHILE AVOIDING THE SUBSIDY TRAP

As other countries during their structural transformation, (Japan, Europe and the US), China has started to increase its support to its farmers. Farm expansion

through institutional innovation and investment in technology and rural infrastructure, has so far been advanced as the major vehicle to resolve the farm income problem. But as illustrated in the numerical example in Box 3, these may not materialize fast enough and are unlikely to suffice for everyone, raising the pressures for more direct (and visible) support. Such pressures have been encountered by countries across the world as they transitioned through their structural transformation¹³⁹ and have usually given rise to a rapid increase in agricultural subsidization and protection. This process is also being played out right now in China.

Producer support has risen substantially over the past decade, from being negligible around the turn of the century to 17 percent of gross farm receipts in 2010 (Figure 17). Though fluctuating in an attempt to balance producer and consumer interests, especially during the 2007–2008 food price crisis,¹⁴⁰ (distortionary) market price support¹⁴¹ has been the main, and since 2009, a rapidly increasing source of support for Chinese farmers. But budgetary transfers/subsidies have also increased rapidly, from being negligible (RMB 100 million) in 2002 to about RMB 147 billion (US\$21.5 billion) in 2010 (Figure 17). They started with direct income transfers based on grain planted areas in grain surplus producing provinces in 2004 and have since been complemented with rapidly increasing input subsidies for agricultural chemicals, which now make up the bulk of the subsidies. Subsidies for improved seeds, machinery, and since 2007, also insurance, have also been growing rapidly over the past couple of years (Table 4).

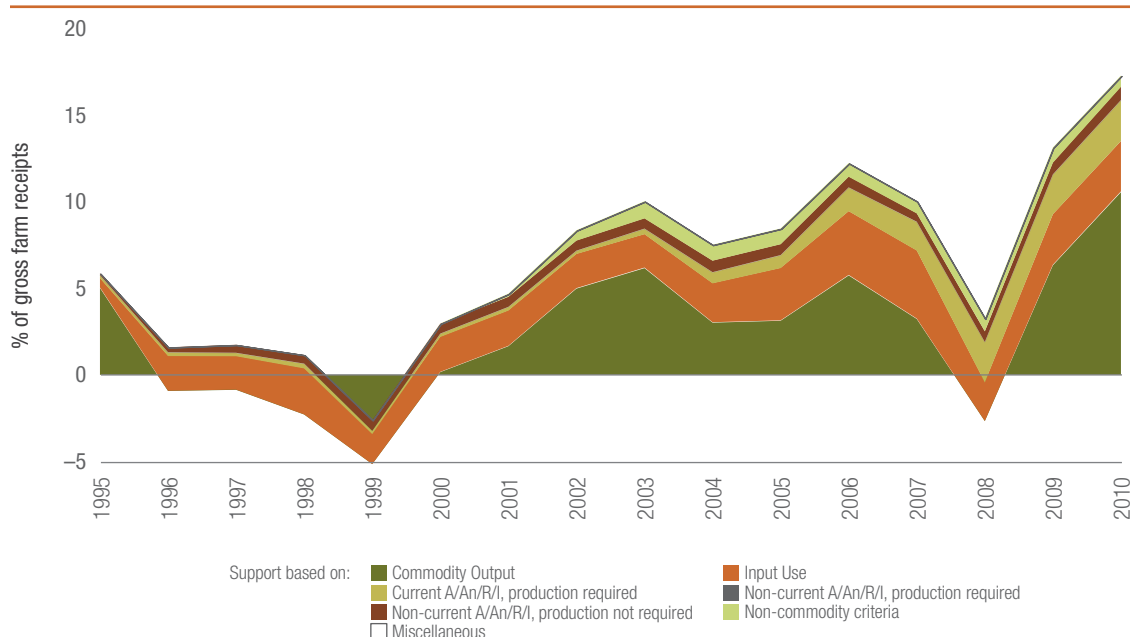
¹³⁹ Timmer (2009).

¹⁴⁰ The negative market price support in 2008 was largely driven by a dramatic rise in world rice prices that was not transmitted to the domestic markets (Fang, 2010).

¹⁴¹ This is represented by commodity output in Figure 17 and comes through tariffs, tariff rate quotas and state trading combined with minimum guaranteed prices for rice and wheat.

FIGURE 17

SUPPORT TO AGRICULTURAL PRODUCERS RISING RAPIDLY IN CHINA, MOST RECENTLY THRU PRICE SUPPORT



Source: OECD (2011).

TABLE 4

RAPID INCREASE IN SUBSIDIZATION OF AGRICULTURE 2002–2010

Billion yuan	Grain planting subsidy (direct payment)	New Variety Extension Payment	Machinery subsidy	Comprehensive subsidy on agric inputs	Ag insurance	Total
2002	0	0.1	0	0	0	0.1
2003	0	1.1 ^a	0	0	0	1.1
2004	11.6	2.1 ^a	0	0	0	13.7
2005	13.2	3.1 ^a	0.5	0	0	16.8
2006	14.2	4.1	1.9 ^a	12	0	32.2
2007	15.1	6.7	3.3	27.6	2.15	54.9
2008	15.1	12.1	5.6	71.5	4.87 ^a	109.2
2009	15.1	19.8	13.0	79.5	9.02 ^a	136.4
2010	15.1	20.4	17.8	83.5	10.3	147.1

Sources: OECD (2009, 2011); Lei Meng (2010).

^a linearly interpolated due to missing observations

But to avoid growth in economically and environmentally costly subsidies and maintain consistency with WTO commitments, agro-chemical subsidies should be

eliminated and decoupled (conditional) income transfers expanded and targeted to support farmers' incomes. Even though the early experience with the comprehensive input

subsidies was not found to distort input allocation and cropping decisions,¹⁴² China may rapidly use up its WTO allowances when continuing along the current path.¹⁴³ Moreover, in addition to the comprehensive input subsidy, there is an additional set of policy measures aimed at lowering the prices of chemical fertilizers.¹⁴⁴ These have been lowered from CNY 89.5 billion in 2007 to an estimated CNY 35.6 billion in 2010, but should be eliminated altogether to discourage current overconsumption of fertilizers and remedy nonpoint source pollution.

A general way forward to avoid input subsidies and price supports to meet WTO commitments while continuing support to farmers, is to expand (conditional) income support policies, decoupled from production, in addition to better targeting subsidies to reign in their growth. Unconditional decoupled income support programs have been successfully applied in Mexico under the Pro-Campo program, but conditions could be usefully added to simultaneously address “field problems”, as currently practiced under the Grain for Green program. Similarly, farmers’ incomes could be supplemented when they adopt more sustainable land management practices. Other innovative uses of income support include the issuance of advances against future income streams. Alternatively, future income support streams could also be recognized as collateral for credit, to relax farmers’ credit constraints, as in Pro-Campo in Mexico. Doing so, would require an acceleration of public registries that clarify and formalize property rights, such as to land and water.

¹⁴² Huang and Rozelle (2011).

¹⁴³ See Yu and Jensen (2010) for more detailed descriptions. As a significant share of the budgetary support programs are paid at a flat rate per unit of land, with no apparent enforceable requirements to purchase certain inputs or plant certain crops, they could be seen as direct (non-distortionary) income support (OECD, 2011). This has so far been consistent with farmers’ behavior observed in the field (Huang and Rozelle, 2011). Yet, the allocation of subsidies is in practice also one of the few instruments local officials have to ensure their jurisdictions attain the grain production quota given to them, which is now also an explicit benchmark in considering officials for promotion.

¹⁴⁴ These include preferential prices for electricity and natural gas for fertilizer producers, preferential transportation prices for fertilizers, an exemption from contributing to the rail construction fund and an exemption from VAT.

4.5 IMPROVE AGRICULTURAL WATER AND ANIMAL WASTE MANAGEMENT

Base water management on actual consumption and reduce pollution. To tackle China’s growing water scarcity and its unequal regional distribution, water use in agriculture must be more actively managed. In addition to reducing overall demand through increased reliance on import of water intensive crops, there is now also substantial scope to develop a water management system based on the monitoring and regulation of actual consumption using more sophisticated measures of water consumption/evapotranspiration. In particular, the amount of water actually consumed in agriculture can now be measured through satellite based remote sensing and geographic information system technologies.

Better water management in agriculture also requires better pollution control. On the one hand, agriculture is the most important source of nonpoint pollution, primarily related to increasing fertilizer and pesticide runoff from farmland and infiltration of livestock waste. In addition to a series of measures to reduce fertilizer use, proper regulations (including zoning of livestock production) and animal waste management practices will be needed to reduce nutrient leaching to ground and surface water from the increasing concentration of intensified livestock production in (peri-) urban areas. This will further

reduce the atmospheric emissions of excess nitrogen and the increased risk of animal and human pandemics, such as avian flu. On the other hand, agriculture also uses large amounts of wastewater, most of which is untreated. This poses substantial risks to public health and soil quality.¹⁴⁵ About 4.1 million hectares, or 7.4 percent of the irrigated lands, are irrigated with polluted water.¹⁴⁶

Use economic tools (water pricing and trading) supported by appropriate institutional arrangements to better manage water use. Appropriate pricing for water use and pollution discharge, and further piloting of water rights trading can go a long way in managing water more effectively. In a first step, irrigation fees should cover all system operations and maintenance costs, with the fees adapted over time to also cover rehabilitation and expansion costs. This will help induce a geographical shift in cropping patterns, concentrating water intensive crops in water abundant areas, while promoting higher value water crops (higher net return per m³ water consumed) in water scarce areas. Efficiency gains can further be obtained, while protecting the rights of existing users, through the issuance of clear and enforceable water user rights, and water trading based on water consumption. By regulating the total amount of water use rights, broader damages from over-utilization of water could be addressed efficiently. To do so, more efforts will be needed to strengthen the administration of water use rights, with rules in place to protect against arbitrary changes in rights and better provisions to resolve issues when user rights are negatively affected.¹⁴⁷ Well functioning water users

associations will be necessary to implement better water management practices, as well as strong river basin authorities that include and represent the interests of all stakeholders and help resolve inevitable conflicts.

4.6 MANAGE RISKS BETTER

Adaptation to climate change in agriculture will involve expanding trade, technology and better short term risk management based on refined agro-weather and climate information. Rising uncertainty about the production environment is the defining feature of climate change—adding a new layer of uncertainty to a production system that is intrinsically uncertain to begin with. To diversify risk, adaptation in agriculture will involve expanding trade. This will help diversify weather/water risks across different regions of the world to mitigate short run harvest failures. Expanded trade is also consistent with more diversified and higher value-added production, greater emphasis on ecological restoration and less over-use of marginal lands, and greater emphasis on ecological services particularly for water conservation in water scarce regions. In parallel to diversification via trade, R&D should continue to develop drought, heat and flood resistant seed varieties of the major crops. The important steps being taken should be strengthened. Finally, improved agro-weather and agro-climate information and services for farmers can improve climate resilience across the agriculture value-chain, including production, post-harvesting, storage, and market access.¹⁴⁸ Weather-indexed insurance schemes, with payouts triggered if a specified

¹⁴⁵ According to Jimenez and Asano (2008), China is the country with the largest amount of wastewater reuse worldwide, estimated at 15 million m³ per day.

¹⁴⁶ Xie (2009).

¹⁴⁷ Xie (2009).

¹⁴⁸ For example, applying a “fungicide application timing” tool developed by the US Southeastern Climate Consortium AgroClimate for a strawberry farm in the United States, the farmer showed a \$3 million dollars saving and 50% reduction of the fungicide.

weather events passes a given threshold (e.g. rainfall falls below a certain level) hold further promise to manage weather related risks. Targeted subsidies may be considered, especially for poorer farmers and to overcome fixed costs in establishing markets.

Agriculture is also an important sector for achieving the national target of reducing carbon intensity by 40–45% by 2020—the mitigation agenda. China's agricultural sector contributes the most greenhouse gases after power, contributing 14% of its total emissions or about 6.8 Gt of CO₂ equivalents per year. Emissions are mainly from the release of soil carbon, crop burning, and methane and nitrous oxide produced during rice production and by livestock and livestock waste. At the same time agriculture

is vulnerable to climate change, via changes in precipitation, temperature, drought, storms, and increased CO₂ in the atmosphere. Agronomic technology choices and investments made today need to take into account both the likely impact of future changes in climate on production as well as their likely impacts on future changes in climate. Mid-season drainage, for example, can be an effective option to mitigate the carbon-footprint of rice fields, especially when larger amounts of rice straw are returned to the soil and when N fertilizer application rates are reduced to mitigate the risk that increased N₂O emissions offset reductions in methane (CH₄) emissions. Better water management coupled with more efficient fertilizer application can thus not only save costs. It can also reduce environmental risks both in the short and long run.

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