Agricultural Production and Food Consumption in China: A Long-term Projection

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Abstract

This paper uses a multi-country and multi-product partial equilibriummodel to forecast foodsupply and demand in China and its impact on food tradein 2050. The model endogenisesshifting consumption preferences due to China's demographic changesand real incomes growthcaused by ongoing urbanisation and industrialisation. We show that total food demand in China is doublingby 2050 andits structure will shift towards more luxurious goods, away from necessities. While improved productivity growth will enable domestic production to rise, imports are still likely to play an important role in reducing the "quality" gap in future Chinese food demand.

Key Words: Partial Equilibrium Model, Long-term Food Demand, China Agrifood Production

JEL Code: Q17, N55, E17

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Introduction

The rapid economic growth in China has lifted the level of its real income per capita over the past four decades (OECD 2012). This, combined with a steady expansion of its total population, has not only increased total food demandbut also changed the structure of food consumption. In 2011, apparentconsumption of major agricultural commodities including cereals, meat, dairy products, vegetables and fruits in China were 211.9 million tons, 80.4 million tons, 44.1 million ton and 578.8 million tons respectively, which were 1.5 times, 7.3 times, 14.8 times and 9.9 times of those in 1978. In particular, per capital consumption of dairy products and vegetables and fruits both increased by more than ten times, which were much higher than that of meat (5.1 times) and cereals (1.5 times). Moreover, since total population and real income per capita in China are still increasing, it is expected that China's food demand will sustainably drive up world market prices in particular for specific commodities such as major cereal products and red meat (Linehan et al. 2012).

To meet domestic food demand, agriculture is treated as one of the key strategic industries in China. Although its contribution to GDP and total employment fell over time, China's gross output of major agricultural commodities continued to rise. Between 1978 and2013, the production of paddy rice and pigmeat (two major food products) increased from93.4 million tons and 8.8 million tonsto 135.2 million tons and 49.4 million tons, respectively (FAO 2014). This rise in agricultural output occurred with only modest rises in arable land and labour usage (5 per cent and 1.7 per cent increase in arable land and efficient labourusage over the same period, respectively). Productivity growth, partly due to large scale of migration resulting from institutional reforms which lowered labour/land ratios, technological progress and infrastructure investment, have played an important role in contributing to the output increase. Over this period, the annual growth rate of agricultural total factor productivity (TFP) and labour productivity in China were 2.8 per cent and 4.3 per cent respectively, which are much higher than the world average of 1.0 per cent per annum for both total factor productivity and labour productivity(Fuglie and Rada 2015).

Given China's growing importance in world food markets, it is of great interest to academics and policy makers to understand future food demand and supply in China and its implication for global food trade. This has led to the development of various partial and general equilibrium models aimed primarily at projecting China's food demand and supply in the near future. The widely used partial equilibrium models include the USDA CPPA and ChinaAg models (Hjort and van Peteghem 1996), the IFPRI International Model for Policy Analysis of Agricultural Commodity and Trade (IMPACT) model (FAPRI 1996, IFPRI 2012), the World Bank Econometric Simulation Model (WBESM) (Fan 1997), Overseas Economic Cooperation Funds of Japan (OECF) model and the FAO World Food model (Frohberg and Britz1994) and the OECD-FAO AGLINK-COSIMO model (OECD 2001);while the general equilibrium models include the global trade and agricultural project (GTAP), G-Cubed and global trade and environmental model (GTEM) models.[1]

Results from previous studies, though differing in magnitude, generally demonstratedthat China’s consumption of cereals and grains will continue to rise in the long run. Furthermore, with resource constraintswith respect to both land and labour, thisincreased food demandwas expected to be met increasingly by importsof a large amount of wheat and rice if there is no further breakthrough in production technology (Fan 1997). However, this finding is yet to be proved accurate as the past decade witnessed a rough balance between the supply and demand for cereals and grains in China. Surprisingly, China even startedto export paddy rice to the international market since 2014. A possible explanation of the poor performance of most existing modelsin projecting China’s food demand is that they did not properly account for the change in ‘quality’ of aggregate food consumption due to the changing demographic structure and income growth.

This paper developed a multi-country and multi-commodity partial equilibrium model (Linehan et al. 2013, ABARES 2013) to examineChinese food production, consumptionand trade in 2050. Contributing to the literature, itendogenisesthe shift of aggregate-level consumption preferenceby considering the interaction of different consumption trends of households with different appetites (namely, urban high income, urban low income and rural groups). As such, it provides information regarding the distributional impact of macroeconomic shocks (i.e. changes in demographic structure and per capita income) on aggregatefood consumption between commodities. When combining with the index measuring consumption quality (Clements and Gao 2012), the estimates can demonstrate “quality”escalation in food demand — a phenomenon related to many transitional economies — and its implication for the long-term projection on agricultural production and trade. In addition to the innovation on the demand side, our model also has the flexibility in accessingthe commodity-level impact of different industrialand trade policies so as to provide useful insights for policy making.

The results show thattotal food demand in China will double in terms of real value by 2050 driven by both population and income growth.At the same time, the consumption patterns will shift from necessities (i.e. cereals, grains and starchy staples) tomore luxurious goods, particularly meat and dairy products, reflecting “quality” escalation of food consumption. While the majority of China's future food demand will be met by an increase in domestic production, there are greatpressures for China to increase productivityfor all agricultural products and to open domestic market for foreign investment and trade to boost high value and high protein products to meet the “quality” gap in demand.

The rest of the paper is organised as follows. Section 2 summaries the characteristics of food production and consumption in China. Section 3 discusses the structure of our model and the related assumptions. Section 4 presents data sources on the demand supply elasticities,

[1] In addition to the accuracy of projection, another criticism for the CGE model is that it is operating as a black box and would not provide a clear mechanism on how the food demand and supply are balanced. Also, those studies based on the CGE model are not appropriate for commodity-level policy analysis.

the base year for calibration and policy scenarios. Section 5 provides the projection on China's food demand and supply and discusses the implications for the global food market. Section 6 concludes.

China's Agricultural Production and Consumption

Agriculture is an important industry in China historically, and its ongoing expansion has made a significant contribution to rural economic development and welfare improvement for the Chinese people.Between 1961 and 2012, the gross value of agricultural productionin China increased from US$71 billion to US$594 billion (in 2004-2006 US dollars), representing an annual growth rate of 4.2 per cent a year (FAO 2014). In 2012, Chinese agricultural production accounted for 28 per cent of global agricultural productionin value terms, making it the largest agricultural industry in the world.The industry still employedaround 405million people though the rural population continued to fall (as the result of the rapid pace of urbanisation), and used 515 million hectors of arable land (around 10 per cent of world arable land) (FAO 2014).

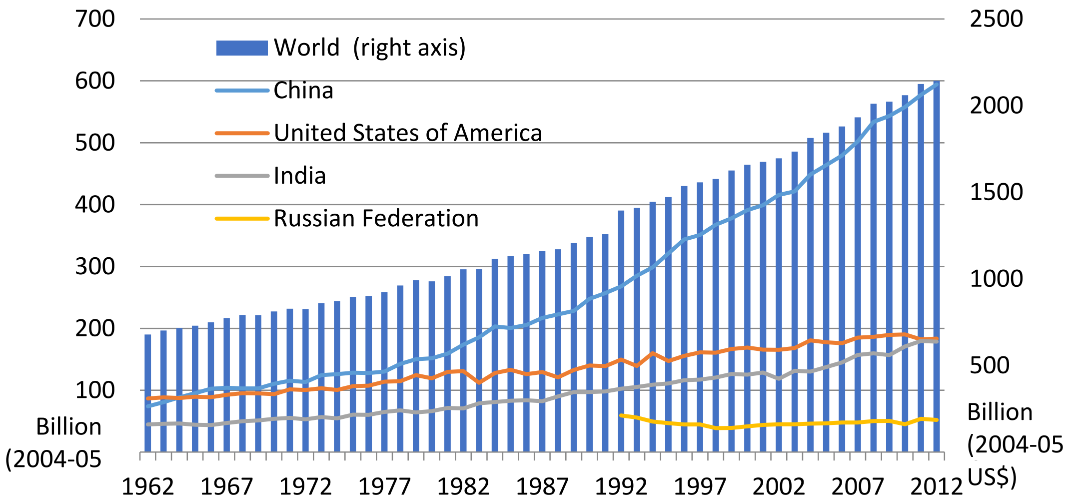

Figure 1 Gross value of agriculture in China relative to other countries and world
Source: FAO STAT database

Compared to agricultural industries of other countries, the Chinese agriculturalindustry is characterised by limited arable land and large labour force engaged in agricultural production. In 2012, the average arable land under permanent crops per person and per farmer were 0.09 ha and 0.24 ha, respectively, which are much lower than the world average (i.e. 0.2 ha and 0.5 ha). The relative scarcity of arable land implies that, in general, China tends to have a comparative advantage in the production of labour intensive crops, such as fruits and vegetables, and a disadvantage in the production of land intensive crops, such as grains and oilseeds (FAO 2014). However, the current product structure of the industry does not reflect the underlying comparative advantage, and instead it reflectsa pattern of production which was determined by the related government policies that favour cereal and grain production to meet domestic demand. In 2011, grains accounted for around 50 per cent of agricultural output, meat, fat and vegetable oils accounted for 22 per cent,and fruit and vegetables 19 per cent. In particular within the production of grains, paddy rice production was most commonin 2012(206 million tons) followed by maize (200 million tons) and wheat (103 million tons).

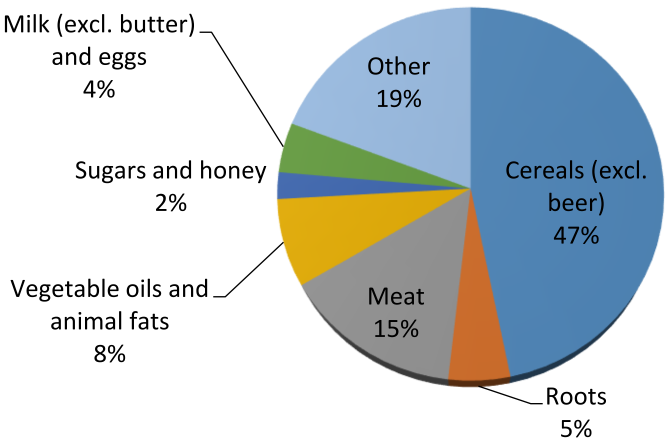

Figure 2 Food group shares in total food supply in China, 2011
Source: FAO STAT database

Government support and subsidies for agricultural production played an important role in facilitating productivity growth, particularly for the grain industry. However, these policies havealso createdmarket distortions in terms of their impact on prices. OECD (2011) showed that the Total Support Estimate (TSE) for agriculture in China is relatively high (at 3.7% of GDP) compared to the average level of OECD countries which is 0.4% of GDP, partly reflecting high levels of government intervention in production, consumption and trade of agricultural products.The intervention of government drove a wedge between domestic and world prices, which was believed to bring additional profits to farmers and the incentive for them to invest in advanced production technologies. As an example, yield growth for grains and oil crops was higher than that of vegetables and fruits in the five decades to 2012, given the consistent focus of government support on grain production (Figure 3)

Although food production and consumption are roughly balanced in China nowadays, thepolicy makers are facing two main challengesover the medium to long term. First, China’s average income per capita is expected to rise continuallyand theproportions of middle class in total population and that of urban populationwill continue to increase. These changes will make China’sconsumption preferencesshiftingfrom grains to high protein and high value products such as red meat, milk products and fruits (Figure 4). However, the current production structure does not reflect this change due to significant policy distortions. Second, there will be limited resources available, particularly land and water,to further increase agricultural output. To increase agricultural output, policymakers will need to consider funding on research and development (R&D) to increase productivity, facilitateinternal reallocation of resources to create more efficient farm structures, improve production technology in small-scale farmers who are currently dominant in the production system, and improvetransparency in implementing agricultural policies (OECD 2012). To address the above two concerns, we believe that the model exercise in this study will provide some usefulinsights and forecast on how changes in government policies could affect the outcome.

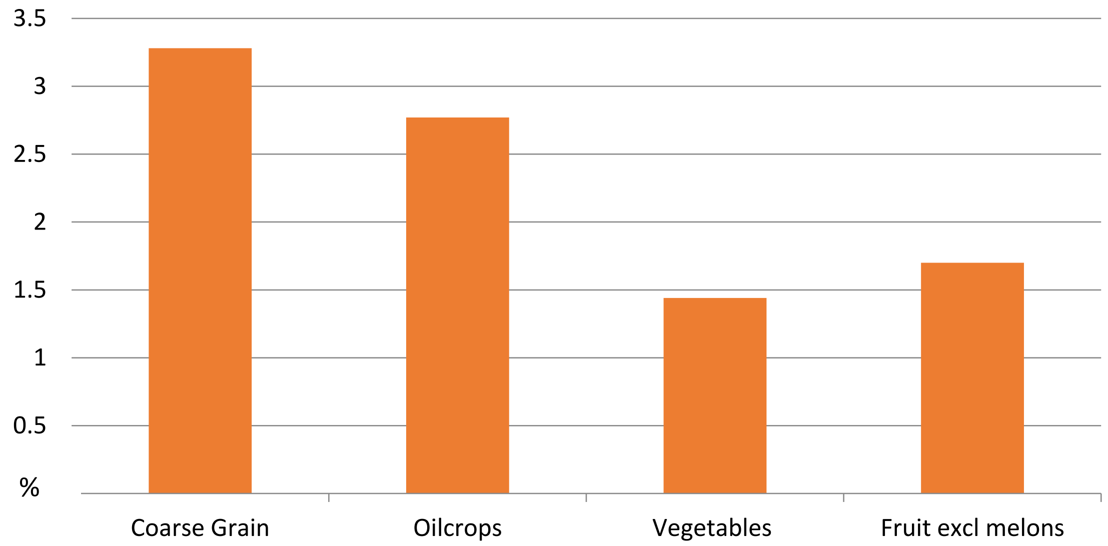

Figure 3 Comparison of yield growthin major crops per annum: 1961-2012
Source: FAO STAT database.

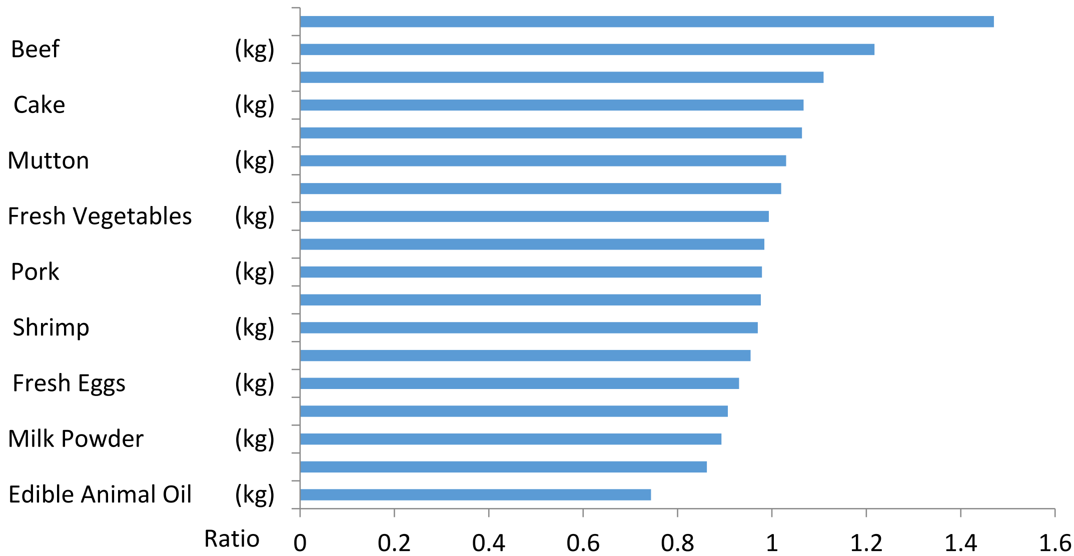

Figure 4 Change in per capita consumption by commodity in China: 2003-2006 (unit: kg per capita)
Source: Authors' estimate by using data from China House Hold Survey (SSB 1996).

Methodology: A Multi-Country and Multi-sector Agrifood Model

The model used in this paper is a multi-region and multi-commodity partial equilibrium model, solved by using the dynamic recursive technique (Linehan et al. 2013). It assumes the world consists of many countries and regions, and each region has only one agricultural industry producing groups of commodities substitutablely across the region with constant elasticity. Consumption is determined by representative agents through maximising their utility with the externally given income and population growth. Production is determined by technological progress and the supply of various inputs (i.e. land, capital and intermediate inputs). Equilibrium is achieved when the aggregate demand and supply of each commodityare equalised, and the surplus in production (or consumption) exports to (or imports from) the world market. The world price, therefore, adjusts to balance aggregate demand with aggregate supply from each region and for each commodity.

The following will briefly discuss the model structure from the perspectives of the demand, supply and market equilibrium.[1]

Demand for Food, Feed and Other Industrial Uses

Aggregate demand for a commodity in a region equals to the sum of food and feeddemand and demand for other purposes (e.g. biofuel and other industrial use). Food demand represents the final consumption demand, while production demand represents the intermediate demand for the production of other agricultural commodities such as feed stuffs, vegetable oils/meals, and livestock/seafood related products among others. Demand for other purpose mainly refers to demand of commercial crops used for biofuel production.

Food demand is mainly driven by real income per capita and population growth, andit is modelled in two layers. At the first layer, demand for food commodity groups are chosen by the representative consumer according to a log linear specification in exogenous real income and endogenous own and substitute prices (as in Equation (1)). Food commodity groups are assumed to include meat and eggs, milk and dairy products, fish and other seafood, cereals, vegetables, fruits, vegetable oils and other food items. The definition of food commodity groups reflects characteristics of various food commodities and their relative substitutability.

$$\log[\frac{qdfoagg}{qdfoagg0}] = edfoincagg * \log(ginci) + \sum_{jagg}[edfopagg * log\left(\frac{pdfoagg}{pdfoagg0}\right)] \quad (1)$$

where the notification in all equations are provided in Appendix A. At the second layer, a constant elasticity of substitution (CES) function is employed to allocate demand between commodities within each commodity group, according to their relative price levels (as in Equation (2)). By assumption, changes in exogenous taste by product are imposed to moderate or amplify outward shifts in demand over time from per capita income and population groups for a particular commodity.

$$\frac{qdfo/qdfo0}{\sum_{iagg} qdfoagg/pdfoagg0} = gtastesubi * \sum_{iagg}[\frac{\frac{pdfoagg}{pdfoagg0}}{\frac{pd}{pd0}}]^{\sum_{iagg} sigmafo} \quad (2)$$

To account for potential structural change in consumption preference at the aggregate level, total consumption is also split into three income strata including urban high, urban low

[1] For detailed discussion of the ABARES Agri-food Model, please refer to Linehan et al. (2013) including explanation of the notation used in equations (1)-(13).

and rural groups. Each income strata have different consumption preferences, determined by their income levels.

Intermediate input demand comes from three industries, including domestic feed production, crop and oilseed meal/fish meal production, and oil concentrate. Demand for individual commodity depends on the output of final consumption product and the related production technologies.

For example, the production of generic feed mix requires using coarse grains as ingredients. To identify such demand for individual coarse grain, we assume that the total volume of feed mix consumed by each livestock type is proportionate to the volume of livestock product output, when the livestock production technology takes the Leontief form (Allen 1968). A CES function is thus used to split the total volume of feed mix into demand for individual crops, according to their relative prices (as in Equation (3)).

$$\frac{\left[\frac{qdfdfmx}{qdfdfmx0}\right]}{\left[\frac{qfdmxact}{qfdmxact0}\right]} = \left[\frac{\frac{pdfdmx}{pdfdmx0}}{\frac{pd}{pd0}}\right]^{sigmamx} \quad (3)$$

Similarly, the production of crushed oil and meal and fish products also requires to use oilseed crops and fishes as intermediate inputs (or throughput) respectively. Assuming there is a Cobb-Douglas transformation function, the growth in demand for those throughputs is thus proportionally to the growth in the total composite crush output, subject to their relative prices (as in Equation (4)).

$$\frac{\left[\frac{qscrml}{qscrml0}\right]}{\sum icruip\frac{qdcru}{qdcru0}} = \frac{\frac{ps}{ps0}}{\sum icruip\frac{pdcrustar}{pdcrustar0}} \quad \text{and} \quad \frac{\left[\frac{qscrol}{qscrol0}\right]}{\sum icruip\frac{qdcru}{qdcru0}} = \frac{\frac{ps}{ps0}}{\sum icruip\frac{pdcrustar}{pdcrustar0}} \quad (4)$$

Finally, for simplicity, demand for biofuel production is assumed to be an exogenous share of total domestic demand.

Production of Agricultural Products

The production of agricultural commodities is modelled separately for individual products, and defined over five production blocksincluding various crops and livestock products, the crush of oilseed crops to meal and oil, fish catch and the production of generic feed mix and fish products.

The production of crop and livestock products is modelled in a similar way. Both types of products use land and other inputs as common inputs, while livestock products require animal feed as additional input (as in Equation (5)). Land demandis linking between various crop and livestock production activities, and allocated (through a competitive market) to individual crop or livestock productiondue to its marginal costs. Land supply is responsive to its real price to account for land conversion from other uses in response to profit opportunities. A finite limit has been imposed as an additional constraint to prevent infinite land expansion. Other inputs are assumed to be sector specific, and its unit costs increase with output of particular products. This limits the unlimited expansion of specific enterprise, allowing competing agricultural land use to expand to some extent, dependent on relevant parameter values. For livestock products, feed use is assumed to take a fixed proportion of output similar as using the Leontief production technology to combine land and feed use. Finally, exogenous technology progress is assumed to improve the efficiency of land, other input and feed usages.

$plndc * iolndc + uopcc \geq ps$ (for crops)

$plndg * iolndl + pdfdmx * iofdmx + uopcl \geq ps$ (for livestock) (5)

The production of oilseed crush sectors is modelled by using a Cobb-Douglas transformation function (as in Equation (6)). Throughout the production process, crushed meal and oil are produced by using oilseed crops and other inputs, where oilseeds are throughputs and other inputs are used to reflect the production efficiency. The unit cost of production is defined to the price of the throughput plusa unit operating cost for crushing, and the zero profit condition ensures that unit revenue from the crush (or the value of output of meal and oil divided by the volume of throughput) equal to operating cost.

$$pd + uopccru = pdcrustar \quad (6)$$

Given the importance of fish product in agricultural production, the supply of fish and fish product is also endogenously modelled. High and low value capture fisheries are distinguished in the model, which are jointly determined by marginal cost of fish capture, resource availability and government policies (namely, quota) to maintain the sustainability. In particular, we assume that annual production must lie within or on quota. To achieve this goal, the rental price of quota is negligible if the quota is not filled; otherwise, the rental price is found where the level of production equates demand with the quota limit. The rental price is then equal to the price received net of unit operating costs (as in Equation (7)).

$$pren + pd * iofdaq + uopcf \geq ps \quad (7)$$

Similar as the production of crush sectors, the production of fish products (i.e. fish meal and oil) also use the fish capture as the throughput and other inputs for marginal costs (as in Equation (8)). Both high and low value fish types are assumed to be perfect substitutes in the production process. An endogenous price premium is incorporated in the model to reflect the imperfect substitution between different types of fish in human food consumption.

$$Pd + Uopcfrd \geq opipfrd * ps \quad (8)$$

Price and Market Equilibrium

In equilibrium, aggregate demand equals to aggregate supply. In other words, domestic production equals to domestic consumption plus export (as in Equation (9)) while domestic consumption equals to domestic production plus imports (as in Equation (10)). This condition ensures that: after accounting for various market mark-up (caused by transportation costs, government tax or subsidy or public/private supportssuch as the import quota, the market support for maize production), there will be a unique market price for each commodity clearing the market. Specifically, the producer price should equal to the domestic market price inflated by the exogenous ad valorem producer support estimate while the consumer price should be equal to the domestic market price deflated by the exogenous ad valorem consumer support estimate, such that.

$$ps = pg * (1 + pse) \quad (9)$$

$$pd = pg * (1 - cse) \quad (10)$$

To account for simultaneous exporting to the world market and importing from the world market of the same good at the same time and place, agricultural product is not assumed to be homogeneous following the Armington assumption (Armington 1969). For each potentially traded good in the model, supply from domestic and foreign source is greater than or equal to demand from domestic and foreign sources (Equations (11)–(13)). A constant elasticity of substitution (CES) function form (following the Armington assumption) is used to split demand between domestic production and foreign supply, and a similar procedure is also applied to supply to domestic and foreign market.

$$qstot + impt \geq qdtot + expt \quad (11)$$

$$pexptfob = pw - tc \quad (12)$$

$$pimptcif = pw + tc \quad (13)$$

In addition, the model also captures the trade related transportation costs as a feature in the prices and trade block. In particular, aunit transport cost to and from the world market is specified to distinguish export from import parity price in the absence of government price interventions. Producer and consumer support estimates are then used in the model to capture government support policies.

A regional switch between exporter, autarky and importer occurs depending on benefit and cost conditions. The price of domestic produce is bound from above by the import parity price and from below by the export parity price. If the domestic unit cost of production is lower than the export parity price, then exports increase until marginal net benefits are zero.

In sum, our model has more flexible and transparent settings to capture public policies comparing with other alternative models. For example, as productivity (from the supply side) and income (from the demand side) are exogenously determined, production and consumption subsidies can be easily added up to the marginal cost of production or the consumption price for policy analysis. In addition, the assumption of a unit transportation cost (or trade barriers) to and from the world market caneasily be used to distinguish export from import parity price (or a price in the absence of government price interventions) to reflect the potential arrangement in trade policies. Finally, when using the index measuring consumption quality (Clements and Gao 2012), the estimates from our model can be used to demonstrate the structural change in “quality” of food consumption.

Data Collection and Compilation

Three groups of data are used to calibrate the model, which include:parameters used to define the demand and supply functions; the production and consumption data for calibrating the model at the base year (i.e. 2009) and;data used to construct macroeconomic shocks. This section briefly discusses the sources of these data.

Parameters of Demand Function and Baseline Data

Parameters used to confine the demand functions of agricultural products in China consist of the income elasticity, own-price elasticity and cross-product price elasticises (Table 1 and Table 2). These elasticises are estimated by using data obtained from Chinese Household Survey between 2003 and 2009. To capture difference in consumption preference of various income groups, elasticises are estimated for urban high-income, urban low-income and the rural population independently. Generally, the urban high-income group has relatively higher income and own-price elasticity of highprotein and highvalue goods than the urban low-incomegroup and rural group. This is consistent with our expectation of the change in food consumption preference as real income increases.

Table 1 Income and Own-price Elasticisesfor different income groups by commodity

	Income Elasticity			Own-price Elasticity		
Commodity	Urban High	Urban Low	Rural	Urban High	Urban Low	Rural
Pork	0.311	1.997	2.553	-0.277	-0.273	-0.200
Beef	0.909	0.457	0.478	-1.709	-1.203	-0.770
Sheep	2.943	2.827	1.228	-0.809	-0.547	-0.294
Poultry	6.267	8.939	9.495	-3.876	-5.269	-5.844
Eggs	1.782	1.442	2.363	-0.656	-0.367	-0.336
Milk	0.434	0.251	0.147	-0.287	-0.193	-0.145
Fish	13.796	3.407	3.534	-0.229	-0.657	-0.391
Fish (High Value)	14.375	7.005	2.191	3.014	1.253	1.137
Grains	0.795	0.368	1.625	0.017	-0.002	0.017
Oilseeds	0.220	0.822	2.470	-0.043	-0.031	-0.073
Vegetables	1.918	0.217	1.311	-1.113	-0.492	-0.079
Fruits	1.410	0.742	0.221	-0.751	-0.040	-0.294

Source: Authors' estimation by using data from Gould and Dong (2004).

Table 2 Average cross-product price elasticizes

Commodity Name	Code in Model	Cross-product Elasticity
Beef and Mutton	Pork	0.095
Beef and Mutton	Poultry	-0.008
Beef and Mutton	Fish	0.022
Beef and Mutton	Vegetable	0.012
Beef and Mutton	Fruit	-0.015
Beef and Mutton	Rice	0.014
Beef and Mutton	Grain other	-0.022
Beef and Mutton	Dairy product	-0.042
Beef and Mutton	Egg	0.013
Beef and Mutton	Oil and fat	-0.026
Beef and Mutton	Food away from home	-0.167
Pork	Beef and Mutton	0.071
Pork	Poultry	0.018
Pork	Fish	-0.11
Pork	Vegetable	0.053
Pork	Fruit	-0.094
Pork	Rice	-0.022
Pork	Grain other	-0.026
Pork	Dairy product	-0.126
Pork	Egg	0.041
Pork	Oil and fat	0.013
Pork	Food away from home	-0.515
Poultry	Beef and Mutton	-0.011
Poultry	Pork	0.045
Poultry	Fish	0.021
Poultry	Vegetable	0.02
Poultry	Fruit	-0.04
Poultry	Rice	-0.16
Poultry	Grain other	0.011
Poultry	Dairy product	0.045
Poultry	Egg	0.063
Poultry	Oil and fat	-0.037
Poultry	Food away from home	-0.211
Fish	Beef and Mutton	0.027
Fish	Pork	-0.14
Fish	Poultry	0.017
Fish	Vegetable	0.075
Fish	Fruit	0.044
Fish	Rice	-0.122
Fish	Grain other	0.041
Fish	Dairy product	-0.022
Fish	Egg	0.073
Fish	Oil and fat	-0.009
Fish	Food away from home	-0.057
Vegetable	Beef and Mutton	-0.005
Vegetable	Pork	0.056

Commodity Name	Code in Model	Cross-product Elasticity
Vegetable	Poultry	0.013
Vegetable	Fish	-0.052
Vegetable	Fruit	-0.046
Vegetable	Rice	0.01
Vegetable	Grain other	-0.124
Vegetable	Dairy product	-0.04
Vegetable	Egg	0.063
Vegetable	Oil and fat	0.023
Vegetable	Food away from home	-0.049
Fruit	Beef and Mutton	0.001
Fruit	Pork	-0.104
Fruit	Poultry	-0.017
Fruit	Fish	0.048
Fruit	Vegetable	0.063
Fruit	Rice	-0.126
Fruit	Grain other	0.033
Fruit	Dairy product	0.066
Fruit	Egg	0.094
Fruit	Oil and fat	-0.04
Fruit	Food away from home	0.277
Rice	Beef and Mutton	0.021
Rice	Pork	-0.058
Rice	Poultry	-0.183
Rice	Fish	-0.193
Rice	Vegetable	0.025
Rice	Fruit	-0.185
Rice	Grain other	0.126
Rice	Dairy product	-0.116
Rice	Egg	0.285
Rice	Oil and fat	0.153
Rice	Food away from home	-0.241
Grain other	Beef and Mutton	0.001
Grain other	Pork	0
Grain other	Poultry	0.026
Grain other	Fish	0.046
Grain other	Vegetable	0.18
Grain other	Fruit	0.029
Grain other	Rice	0.074
Grain other	Dairy product	0.096
Grain other	Egg	0.061
Grain other	Oil and fat	-0.087
Grain other	Food away from home	0.436
Dairy product	Beef and Mutton	-0.067
Dairy product	Pork	-0.235
Dairy product	Poultry	0.054
Dairy product	Fish	-0.04
Dairy product	Vegetable	0.101

Commodity Name	Code in Model	Cross-product Elasticity
Dairy product	Fruit	0.07
Dairy product	Rice	-0.114
Dairy product	Grain other	0.102
Dairy product	Egg	0.065
Dairy product	Oil and fat	-0.049
Dairy product	Food away from home	-0.339
Egg	Beef and Mutton	-0.02
Egg	Pork	0.114
Egg	Poultry	0.09
Egg	Fish	-0.138
Egg	Vegetable	0.171
Egg	Fruit	-0.18
Egg	Rice	0.338
Egg	Grain other	-0.117
Egg	Dairy product	-0.07
Egg	Oil and fat	0.002
Egg	Food away from home	-0.052
Oil and fat	Beef and Mutton	-0.073
Oil and fat	Pork	0.037
Oil and fat	Poultry	-0.066
Oil and fat	Fish	-0.023
Oil and fat	Vegetable	0.069
Oil and fat	Fruit	-0.102
Oil and fat	Rice	0.225
Oil and fat	Grain other	-0.209
Oil and fat	Dairy product	-0.081
Oil and fat	Egg	0.001
Oil and fat	Food away from home	-0.275
Food away from home	Beef and Mutton	-0.036
Food away from home	Pork	-0.216
Food away from home	Poultry	-0.043
Food away from home	Fish	-0.037
Food away from home	Vegetable	0.058
Food away from home	Fruit	0.043
Food away from home	Rice	-0.085
Food away from home	Grain other	0.093
Food away from home	Dairy product	-0.064
Food away from home	Egg	0.025
Food away from home	Oil and fat	-0.028

Source: Authors' calculation.

Parameters used to confine the supply side are endogenised in the production function of different types of commodities, where only input usage (i.e. land) and production technologies are exogenously determined. Since different types of products use different inputs and intermediate inputs, there is no unique way to specify these parameters. For simplicity, we use the standard setting obtained from the OECD-FAO ARGLINK model (Piero and Londero 2001).

As for the baseline data for calibration, we use the Food Balance Sheets,FAO STAT database (FAO 2016), to provide the related information on the quantities of production, consumption, stock change, imports, exports and intermediate input usages by country and by commodity. The base year is assumed to be 2009 since it is the latestyear when the complete dataset for the whole world is available. Equilibrium world market prices for each commodity are approximated by using the US domestic market price, with the adjustment for transportation costs and other mark-ups for 2009. In addition, data obtained from the Chinese Household Survey are also used to specify the proportion of consumption by different income groups in China for the base year (Table 3).

Table 3 Per capita consumption by commodity (unit: kg/person/per year): 2009

Commodity	Urban High	Urban Low	Rural
bef	9.22	3.02	1.37
pok	43.43	19.07	16.57
she	4.19	1.39	1.65
pul	19.13	5.98	5.86
egg	27.18	9.77	8.25
mlk	64.18	18.10	6.61
whe	30.39	14.85	69.39
rce	19.55	48.04	73.27
mze	3.97	1.45	6.67
oce	0.88	0.32	1.48
pot	5.86	2.07	39.52
spo	4.82	1.71	32.54
ort	1.51	0.55	2.55
soy	6.55	2.28	1.74
soyol	5.31	2.06	1.78
rap	0.00	0.00	0.00
rapol	2.74	1.06	0.92
sun	0.00	0.00	0.00
sunol	0.24	0.09	0.08
ovegol	5.61	2.18	1.88
veg	366.55	124.70	175.12
frt	108.42	30.31	32.12
sugr	16.80	4.86	2.63
fishvd	21.28	13.68	15.47
fislvd	7.25	4.66	5.27

Source: China Household Survey, Chinese Bureau of Statistics.

External Shocksto the Food Demand and Supply

To predict the food demand and supply of China in 2050, it is crucial to use appropriate macroeconomic shocks from both the demand and supply sides. These shocks mainly include the prediction of population and real income growth (the demand side) and the change in the land supply and agricultural productivity (the supply side).

Assumption on population growth for China comes from the medium scenario of the United Nation Population projection. Over the projection period (between 2009 and 2050), the growing trend of total population will take an inverted "U"-shape curve with the average annual growth rate close to zero. Driven by ongoing urbanisation process, urban populations continue to rise and rural populations fall. As a consequence, the proportion of urban population in total population will increase from 46 per cent in 2009 to more than 73 per cent in 2050 (Figure 5).

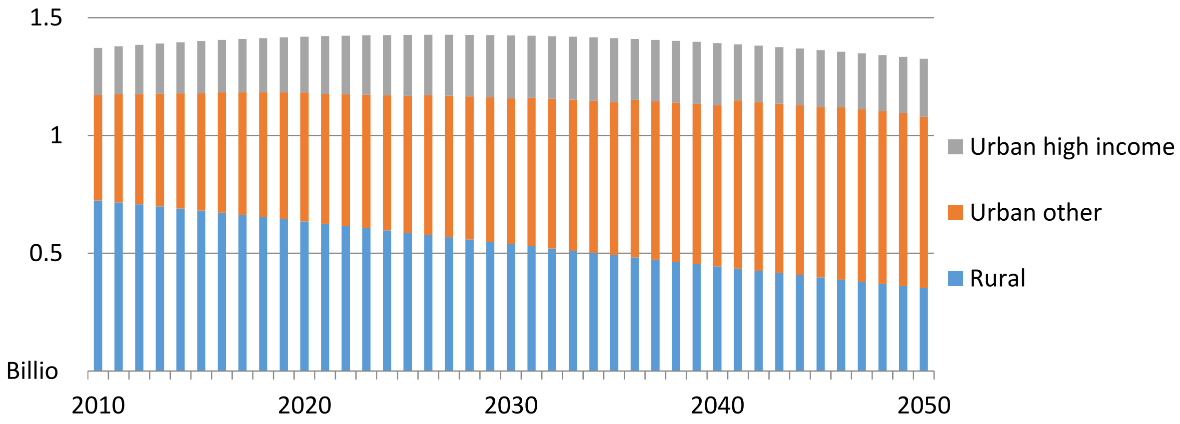

Figure 5Assumption on changing population structure
Source: UN Population Projection.

Assumption on the growth of real income per capita follows that of OECD (2012), which has two characteristics. First, real income growth has been gradually declining over time. For the period of 2011 to 2030, the average GDP growth and GDP per capita growth in China are projected to be 6.6 per cent and 6.4 per cent per annum; for the period of 2030-2050, these two income growth rates will 2.3 per cent and 2.8 per cent per annum. Second, income growth is not evenly distributed across different income groups. When using data from China Household Survey data to decompose real income growth rates by income groups, it shows that urban population generally will have much faster income growth than rural population (Figure 6). This implies that there tends to be an enlarging income gap between urban and rural population and between high income and low income groups. Both population growth and real income growth are summarised in Table 4.

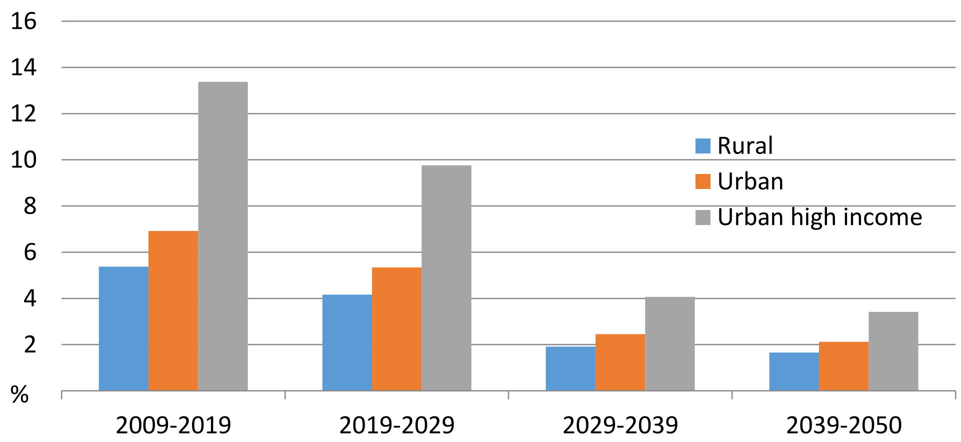

Figure 6Assumption on annual average yearly growth rates

Source: Authors' estimation.

Table 4 Projection on population and real income in China (at constant price of 2009): rural vs. urban

	2009		2020	2030	2040	2050
	RMB Yuan	USD	USD	USD	USD	USD
Expenditure/Income per capita						
Rural Income group	3504.84	513.1	1930.9	2409.1	3708.4	4020.7
Urban Middle Income	8738.79	1279.3	3672.9	4513.4	5674.8	6991.5
Urban High Income	14964.37	2190.7	12760.7	21990.2	32685.6	45835.3
Average Income per capita (2009 USD)		1628.9	8729.2	10854.6	12993.0	14652.9
Total Population						
Rural Income group		198086	253909	287295	299574	300484
Urban Middle Income		462200	592454	670354	699007	701128
Urban High Income		681049	541428	435427	362325	293992
Total Population		1341335	1387791	1393076	1360906	1295604

Source: Authors' estimation.

Assumptions on agricultural productivity growth is estimated by using the historical statistics by commodity (or, based on the business as usual practice). Both yield data at the commodity level obtained from FAO STAT between 1961 and 2012 (FAO 2014) and the total factor productivity and labour productivity at the industry level between 1961 and 2010 estimated by the USDA ERS (Fuglie and Rada 2015) have been used for this projection. Compared to productivity projections used by other studies, our estimates show relatively higher productivity growth in grain, vegetable and fruit industries while a relatively lower productivity growth in beef, sheep and poultryindustries (Figure 7). Since the production process for vegetables and fruits involves more labour usage relative to beef, sheep and non-irrigated grains and over time government gave more support to the production of the low value commodities, this pattern in productivity growth between commodities is more likely to reflect the comparative advantage of agricultural production in China and the effects of some supportive policies from the government.

Finally, it is assumed that the land supply to agricultural production declines by 15 per cent between 2009 and 2050. This assumption is reasonable due to the historical experience in China. Although the ongoingurbanisation and industrialisation has reduced the arable land by 15 per cent between 1990 and 2009.

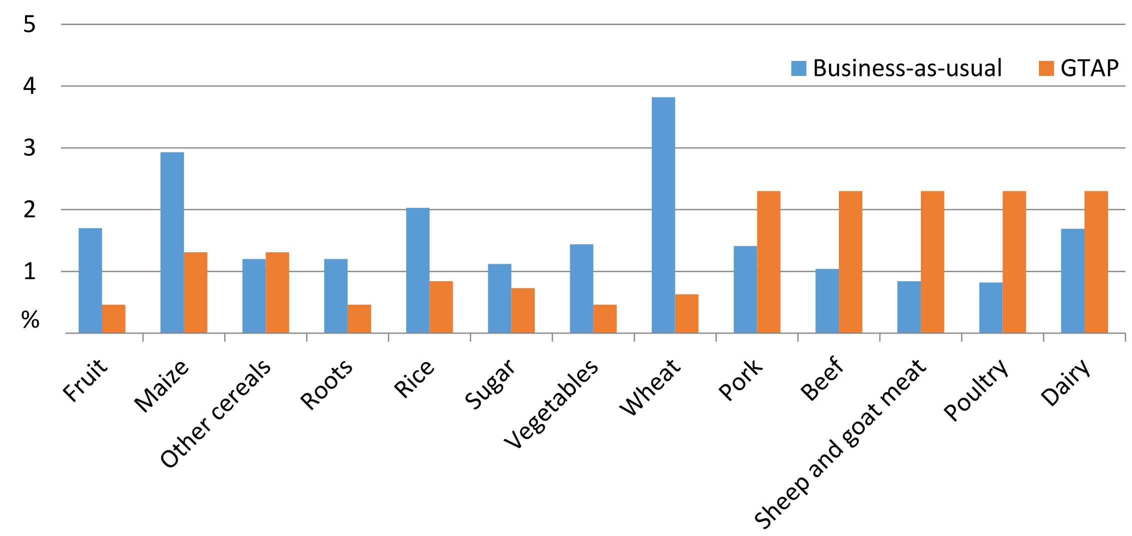

Figure 7Comparison of various productivity growth scenarios
Source: Authors' estimation.

China Food Demand and Supply in 2050

Using the model with predicted changes in population, real income and agricultural productivity as external shocks, we forecast food demand and supply in China and its implications on trade of agricultural products by 2050.

Food Consumption

The real value of total food consumption in China is projected to increase by 104 per cent by2050 (Figure 8). Such a change reflects not only a quantity increase in consumption but also a mild increase in consumption price. Consumption growth increases more quickly before2030 than from 2030 to 2050 because of projected higher population and income growth over the earlier period.

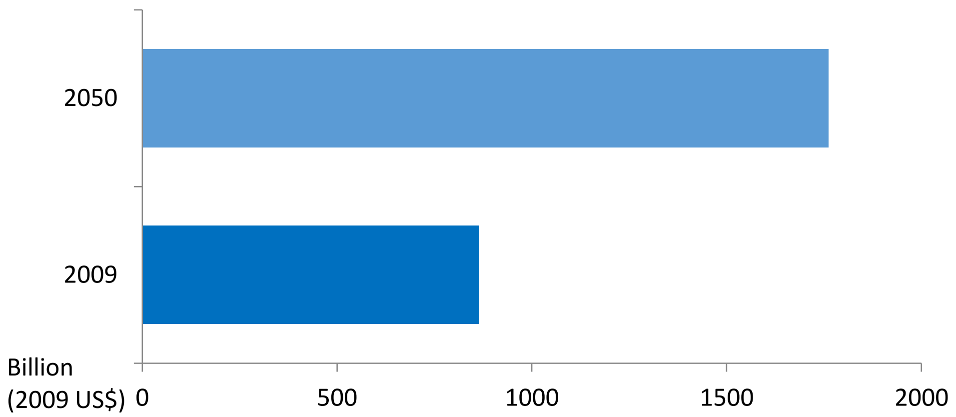

Figure 8 Total food consumption in China
Source: Authors' forecasts.

While consumption of most commodities is projected to rise, the largest increases are for high value products such as beef, dairy, sheep and goat meat, and sugar (Figure 9).By 2050, beef consumption is projected to rise by 236 per cent to US$37.4 billion, dairy is projected to rise by 74 per cent to US$26.1 billion, sheep and goat meat is projected to rise by 72 per cent to US$7.9 billion and sugar consumption is projected to rise by 330 per cent to US$8.2 billion (in 2009 US dollars).

In contrast, consumption of grains and some selected vegetables is projected to grow relatively slow. For most cereals and starchy staples including rice, potatoes, yams and sweet potatoes among others, consumption is projected to either increase more slowly than higher valued products or even decline by 2050. However, there is an exception for maize consumption, which is projected to rise by 9 per cent to US$27.0 billion (in 2009 US dollars). The increase of maize consumption largely reflects the projected increase in feed demand given the expected rise in livestock production.

The more rapid growth in demand of meat and dairy products than that of grains reflects adietary shift away from staple foods such as cereals, to high valued products as real per capita incomes increase.In other words, as income per capita increases and demographic structure changes, China's food consumption will experience a rapid escalation in quality in the long run. Using the index of the changing "quality" in food consumption (Clements and Gao 2012), we further measure the degree to which the consumption basket as a whole moving towards more luxurious goods, away from necessities, and its components. By 2050, there are around 14 per cent increase in expenditure for food quality in China, comparing to 2 per cent increase in the rest of the world. Among this change, more than 85 per cent (i.e. 12 per cent) comes from the change in food quality while only 15 per cent (i.e. 2 per cent) is attributed to the price effects.

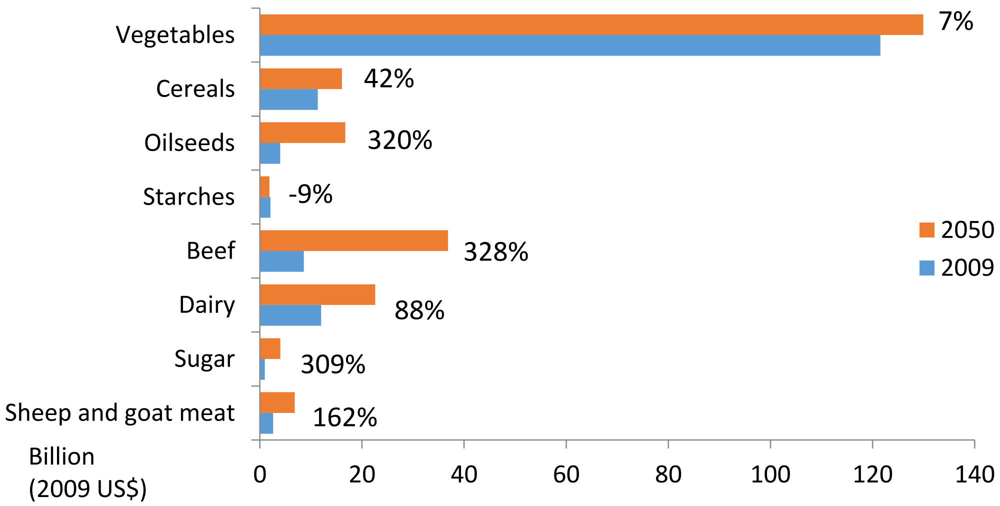

Figure 9Consumption of high value products
Source: Authors' estimation.

To explain the change in China's food demand in 2050, two important factors deserve to be mentioned. On one hand, the increase in income per capita and population will raise the total food demand and shift the food consumption structure towards luxuries (rather than necessities) products. However, these changes only gradually affect the structure of food consumption which have already been captured by existing studies.[1] On the other hand, the changing demographic structure, a result of ongoing urbanisation, will contribute more substantially and more quickly to the shift in dietary structure. As more rural migrants move into cities, urban consumers' preference in food consumption will dominate rural consumers' preference. As such, there will be a rapid increase in the quality of food consumption, such that more consumption of high valued products and its growth, rising urban populations and real incomesover the projection period, will dominate aggregate food consumption.

Food Production and Trade

Driven by increased demand (and thus the commodity price in domestic market) and productivity growth, China's production of agrifood products is projected to increase for almost all commodity groups (Figure 10). However, constrained by limited input growths (mainly land and water), the increased output is generally smaller than that of consumption. As a consequence, there will be a substantial gap between domestic food consumption and production, in particular for high value and high protein products. By using the index of the changing "quality" in food consumption, we show that there are only 10 per cent of increase in production value for quality improvement which is made up of 9 per cent increase in quality of volume and 1 per cent increase in quality of price. This implies that domestic food supply is unlikely to satisfy domestic food demand in structure even if the total amount of food production is sufficient enough, and food imports will play an important role in China's food supplytoward 2050.

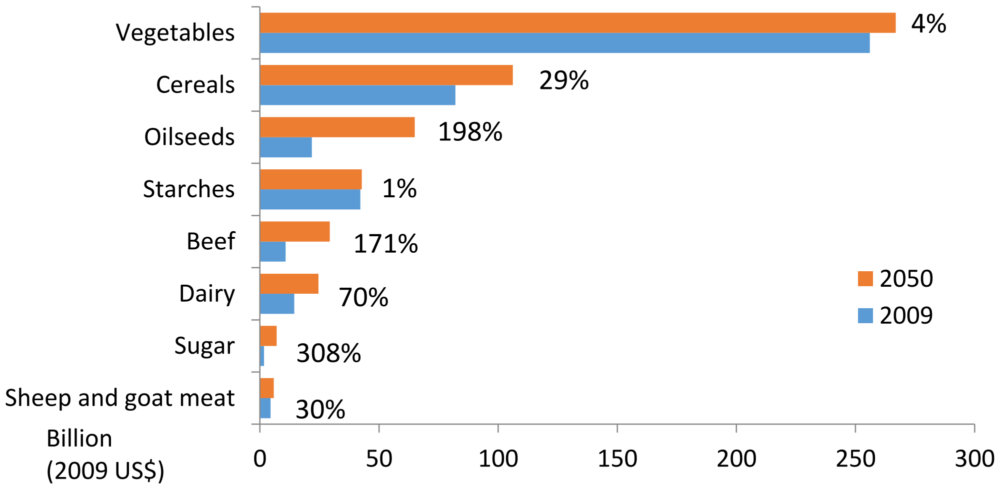

Figure 10 Production of selected commodities
Source: Authors' estimation.

[1] In this paper, the aging problem and its potential effects on aggregate food consumption have been taken into account through this channel.

Specifically, China's consumption of rice, vegetables, pig meat and poultry meat has been mainly met by domestic production, with trade playing a relatively minor role. Toward 2050, the situation for these commodities is not expected to change significantly and some of these commodities may even change to export. In contrast, a significant portion of China's beef, sheep and goat meat, oilseeds and dairy product consumption is projected to depend on imports. For these commodities, most of the import growth is projected to occur between 2009 and 2030 because of relatively high population and income growth over this period.

Given the enlarged gap between food demand and supply for high quality products in China, there will be great potential for agricultural trade, though the effects could be unevenly distributed by commodity.

High-value commodities: The most significant rise in projected imports is for beef. China is projected to remain a net importer of beef in 2050, with the real value of beef imports projected to increase to US$8.3 billion (in 2009 US dollars). While this projected increase may be large, it is important to note that, in the four years to 2013, annual average import growth was 132 per cent in value terms. If the projection is achieved, the import share of total Chinese beef consumption would be about 22 per cent in 2050, compared with just 7 per cent in 2009.

In addition to beef, net import high-value commodities also include dairy products and sheep meat. China is projected to remain a net importer of dairy products in 2050 with the real value of imports projected to increase by 165 per cent to US$2.1 billion in 2050 (in 2009 US dollars). This growth will see the import share of total Chinese dairy consumption increase from around 3 per cent in 2009 to 8 per cent in 2050. The real value of China’s sheep and goat meat imports is projected to increase significantly to US$2.0 billion by 2050, albeit it from a low base.

Cereals: Although total demand for grain is roughly self-sufficient,China is projected to be a net importer of wheat by 2050 given rising feed requirements. Wheat imports are projected to increase by 299 per cent to US$951.4 million (in 2009 US dollars). While domestic production is projected to meet most of China's wheat demand, imports will account for about 1.2 per cent of China's total wheat consumption in 2050, doubling that of 2009.

To meet domestic demand of feed to support the production of livestock industries, China is projected to remain a net importer of maize over the projection period. However, the real value of China’s maize imports is projected to decline by 14 per cent by 2050 to US$588.5 million (in 2009 US dollars). This will see the import share of total Chinese maize consumption fall from 2.7 per cent in 2009 to 2.2 per cent in 2050, which is equivalent to a 7 per cent fall in the quantity of maize imports to 2.8 million tonnes. The reduction in maize imports will be offset by the decline of maize exports. Over the same period of time, maize exports are also projected to fall by 12 per cent to US$516.4 million.

Further Openness to Trade

What would happen if China is willing to reduce government support and subsidies and open its food market? To answer this question, we forecast food production, consumption and trade of China in an alternative scenarioin which free-trade is assumed. In this scenario, it is assumed that both producer and consumer subsidies and trade intervention policies (i.e. tariffs and quotas) remain unchanged before 2030, and are then removed from 2030 onwards.

Under the free-trade scenario, both the production and consumption of agricultural products will decrease in terms of value due to the decline in the equilibrium consumption price. The real value of China's agrifood production (in 2009 US dollars) is projected to increase by 75 per cent by 2050, a result lower than the reference scenario projection of 109 per cent. This increase in agricultural production, to some extent, reflects the additional benefits that could be obtained from a more efficient reallocation of resource between commodities when market distortions are eliminated. At the same time, agrifood consumption is projected to be 67 per cent higher than in 2009, a result that is 36 per cent lower than the reference scenario (Figure 11).

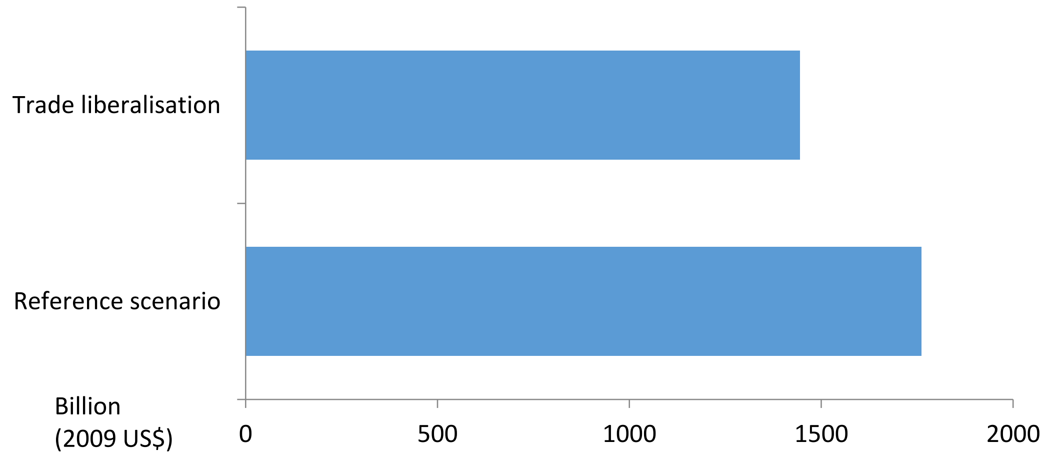

Figure 11Comparison of food consumption: autarky versus openness
Source: Authors' estimation.

However, the real value of China's agrifood imports increases by 150 per cent by 2050, which is lower than the projected increase under the reference scenario of 246 per cent. The lower level of agrifood imports under this scenario reflects reduced agrifood demand, particularly for commodities benefitting from consumer subsidies in the reference scenario, such as wheat, poultry and oilseeds. Imports of these commodities decline the most relative to the reference scenario. In contrast, the commodities whose imports are relatively higher than in the reference scenario include beef (1 per cent), sheep and goat meat (10 per cent), dairy (1 per cent) and vegetables (917 per cent).

Finally, market oriented reforms and open to trade also help to improve the welfare of consumers by facilitating the shift of the food consumption basket as a whole towards more luxurious goods, away from necessities, (or the escalation in quality) in China due to population growth and economic transformation. Comparing between openness to trade scenario and the autarky scenario, the increase in expenditure for food quality (measured by using the index of the changing "quality" in food consumption) under the openness to trade scenario is around 22 per cent which is much higher than that under the autarky scenario (i.e. 14 per cent). Although the price effect partly due to the declining terms of trade for agricultural products (as China is more likely to export the necessities while import the luxuries) has significantly contributed to this increase (say, from 2 per cent to 8 per cent), there is still more than 2 per cent increase in quality of volumeunder the openness to trade scenario relative to the autarky scenario. This implies that market oriented reforms and openness to trade will bring additional benefits by improving the quality of food consumption in China.

Robustness Check

To check whether our projection is sensitive to different demand shocks, we have redone the simulation using different assumptions on population and real income growth. Specifically, for population growth, we use the UN population projection under the assumption of high, low and constant-fertility variant (Figure 12); for real income growth, we use the GDP per capita growth estimated by HSBC and World Bank (Figure 13).

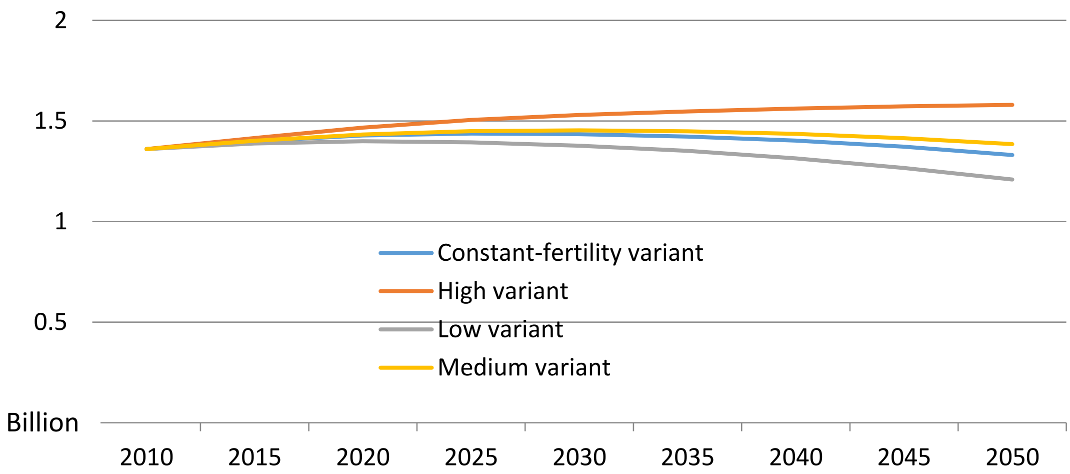

Figure 12Alternative population projections
Source: United Nations (2014).

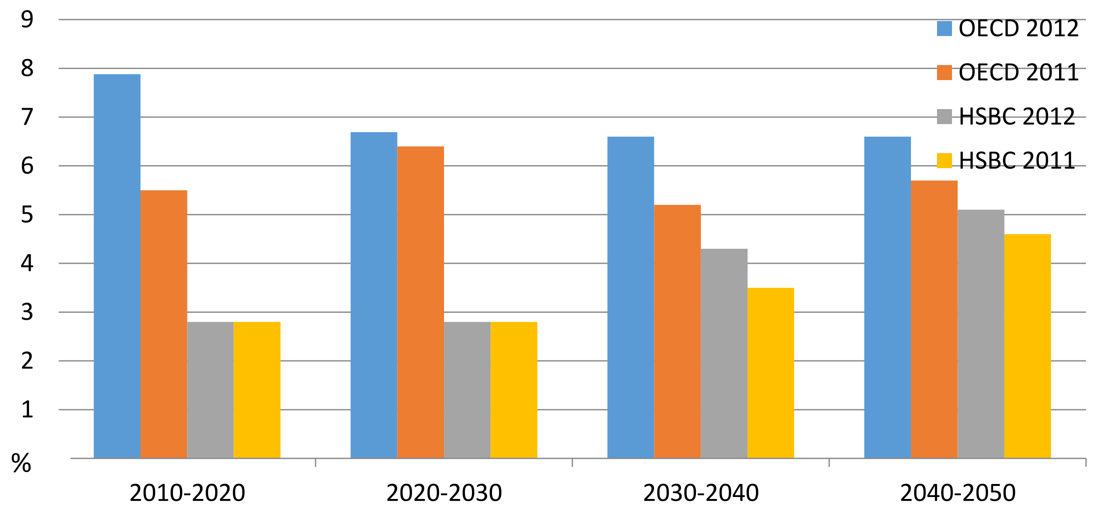

Figure 13Alternative income growth projections
Source: OECD (2012); HSBC (2012).

Although there are some differences in magnitude (not reported), the results obtained from those new simulationsare generally consistent with those obtained from our reference model in terms of food consumption structure. This suggests that our findings are consistent to different assumption of demand shocks.

Conclusions

Under certain assumptions on supply, demand and macroeconomic policies, the real value of food consumption in China is projected to be more than doubledby 2050. Most of this increase will originate from urban middle- and high-income households given their rapid shift to more western-style diets and demand for high-valued commodities like beef, dairy products and sheep and goat meat.The high rate of urbanisation combined with a slowing population growth rate results in structural change in consumption preference and leads to aggregate food demand changing in quality.

Although imports of many agrifood commodities are expected to increase to 2050, China's own agricultural production will largely meet the projected increase in total demand for food, in particular for the necessities. Ongoing investment, technological innovation and further agricultural reforms such as land system, and labour and capital market reform will help to achieve the required rise in food production. Not only must productivity increase, but more modern approaches for contending with the challenges of a deteriorating resource base will need to be adopted. Existing investment rates and initiatives being taken by the Chinese Government would indicate that it is poised to meet these challenges.

Finally, the significant rise in food consumption of more luxuries will be driven by urban middle- and high-income households, which will, to a large extent, be met by imports. In this sense, public policies with the aim to facilitate market-oriented reforms and openness to trade will reduce the costs related to agricultural trade between China and the rest of the world and bring additional benefits to consumers by optimising the distributional impact of changes in the structure of food consumption.

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Appendix A Notations for Variables and Parameters in Equations (1)-(13)

Table A1 Definition of Variables

Item	Description
Production of crops	
qsc(t,n,i)	crop output
uopcc(t,n,i)	unit operating cost of crop supply
lnddc(t,n,i)	land use for crop
Production of livestock products	
qsl(t,n.i)	livestock product output
uopcl(t,n,i)	unit operating cost of livestock product supply
plndg(t,n,i)	rental price on fish quota
lnddgc(t,n,i)	use of crop land by grazing industry
lnddgp(t,n,i)	use of pasture land by grazing industry
Production of fish	
qsf(t,n,i)	production of fish
uopcf(t,n,i)	unit operating cost of fish supply
pren(t, n, i)	rental price on fish quota
qdfimoaq(t,n)	fish meal and oil production
Production of fish meal and oil concentrate	
qdfrd(t,n,i)	fish throughput for reduction
uopcfrd(t,n)	unit operating cost of fish throughput for reduction
qsfimo(t,n)	fish meal and oil production
Production of oilseed meals and oils	
qdcru(t,n,i)	oilseed crush throughput
pdcrustar(t,n,i)	price of Cobb-Douglas complex output
uopccru(t,n,i)	unit operating cost of crush throughput
qscrml(t,n,i)	oilseed crush meal output
qscrol(t,n,i)	oilseed crush oil output
Production of feed mix concentrate for livestock	
pdfdmx(t,n)	price of generic feed mix
qfdmxact(t,n)	generic feed mix produced
qdfdanl(t,n,il)	generic feed mix used by livestock type
qdfdfmx(t,n,i)	use of feed for production of generic mix

Item	Description
Land market balances and total production by commodity	
plndc(t,n)	crop land rental price
plndp(t,n)	pasture land rental price
plndctax(t,n)	shadow tax on feasible land available for crop land
plndptax(t,n)	shadow tax on feasible land available for pasture land
lndsc(t,n)	crop land supply
lndsp(t,n)	pasture land supply
total local production	
qstot(t,n,i)	total local production by commodity
Demand for food, feed and other uses	
qdfoagg(t,n,iagg)	food aggregator quantity
pdfoagg(t,n,iagg)	food aggregator price
qdfo(t,n,i)	food consumption
qdfd(t,n,i)	feed consumption
qdms(t,n,i)	miscellaneous other consumption
qdtot(t,n,i)	total local consumption by commodity
Prices and trade	
ps(t,n.i)	producer price
pexptfob(t,n,i)	export parity price
pd(t,n,i)	consumer price
pimptcif(t,n,i)	import parity price
pg(t,n,i)	local price
expt(t,n,i)	exports
impt(t,n,i)	imports
pw(t,i)	world price

Table A2 Definition of Parameters

Item	Description
Dummy variable mappings	
dvcrush(icruip,i)	dummy mapping crush input to output
dvmkfis(ifs,i)	dummy mapping fish supplies to fish demand types
dvfdagg(if, iagg)	dummy mapping food commodity to food group
Agricultural land	
lndscmax(n)	fixed upper limit on feasible crop land supply
lndspmax(n)	fixed upper limit on feasible pasture land supply
Behavioural	
esc(n,ic)	unit(price) operating cost elasticity of crop supply
esl(n,il)	unit(price) operating cost elasticity of livestock product supply
esf(n,ifs)	unit (price) operating cost elasticity of fish supply
esfrd(n)	unit (price) operating cost elasticity of fish throughput for reduction
escru(icruip, n)	unit (price) operating cost elasticity of oilseed throughput for crush
sigmamx(n)	ces elasticity of substitution between inputs in livestock feed mix
eslndc(n)	own price elasticity of supply of crop land
eslndp(n)	own price elasticity of supply of pasture land
edfoincagg(iagg,n)	income elasticity of demand for food type
edfopagg(iagg,jagg,n)	own and cross-price elasticity of demand for food type
sigmafo(n,iagg)	ces elasticity of substitution between foods in food type
Behavioural input-output and output-input coefficients	
iolndc(t,n,ic)	index for exogenous trend in uopcc
tcuopcli(t,n,il)	index for exogenous trend in uopcl
tcuopcfi(t,n,ifs)	index for exogenous trend in uopcf
tcuopcfrdi(t,n)	index for exogenous trend in uopcfrd
tcuopccrui(t,n,icruip)	index for exogenous trend in uopccru
Exogenous environment	
gafi(t,n,ifsc)	index for exogenous trend in substainable fish supply
ginci (t,n)	real income index
gtastesubi(t,n,ifo)	taste shifter index for food demand
shms(t,n,i)	share of miscellaneous other demands in total demand (fraction)
pse(t,n,i)	ad valorem producer support estimate (fraction)
cse (t,n,i)	ad valorem consumer support estimate (fraction)
tc(t,n,i)	unit transport cost to and from the world market