Received: 11 November 2017 | Revised: 22 October 2018 | Accepted: 28 October 2018

DOI: 10.1002/agr.21592

RESEARCH ARTICLE

WILEY Agribusiness An International Journal

# Predicting the changes in the structure of food demand in China

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**Funding information**
The Research Base Project of Beijing Social Science Foundation, Grant/Award Number: 18JDGLB046

## Abstract

A complete demand system is estimated separately for urban and rural residents using a two-stage almost ideal demand system–quadratic almost ideal demand system model and pooled provincial and time-series data from 2000 to 2012. The estimated demand elasticities with respect to income and demographic variables are then used to predict the changes in the structure of food demand in China for the year 2030. Results of this study suggest that, as per capita incomes grow further while both urbanization and population aging continue their upward trends, the shares of expenditures on foods away from home are expected to rise while the shares of spending on foods at home would decline, and that at-home food budget shares of grains are expected to continue decreasing whereas at-home food budget shares of foods with animal origins and fruits would be on the rise. Thus, food security in China has been transformed into feed grain security.

**KEYWORDS**

demographic change, food demand in China, income growth, urbanization

**JEL CODES**

C33, D12, Q18

## 1 | INTRODUCTION

Food consumption in China has undergone significant changes over the past two decades. In urban areas, real per capita food expenditures, in 1990 constant prices, increased from 694 Yuan in 1990 to 1438 Yuan in 2016 at an annual growth rate of 2.8%. Whereas, in rural areas, real per capita food expenditures rose at an annual growth rate of 2.6%, from 344 Yuan in 1990 to 676 Yuan in 2016. During the same period, per capita consumption of food grains in China decreased while the consumption of foods with animal origin (including pork, beef, mutton, poultry, aquatic products, eggs, and milk) increased. More specifically, urban residents decreased their per capita at-home consumption of food grains from 131 kg in 1990 to 73 kg in 2016, while they raised their per capita at-home consumption of foods with animal origin from 45 to 77 kg. Between 1990 and 2016, per capita at-home consumption of food grains (unprocessed) for rural residents declined from 262 kg to 157 kg, whereas per capita at-home foods with animal origin rose from 18 to 51 kg.[1] Expenditures on food in China are expected to rise as China continues to evolve into more consumption of animal protein as compared to grains and plant products.

This change in the food demand patterns appears to be closely related to growth in income and rapid urbanization. Engel's law states that food's share of total expenditure declines as expenditures increase. Bennett's law indicates that the “starchy staple ratio” declines as household incomes rise, which suggests a change in dietary patterns toward less consumption of low-value foods such as grains, but more consumption of high-value foods such as meats, milk, and fruits (Timmer, Falcon, & Pearson, 1983). Huang and Bouis (2001) find that changes in lifestyle and food preferences stemming from urbanization have an impact on changes in the structure of food demand. More specifically, urbanization has negative effects on the demand for cereal grains (Huang & David, 1993), while it has positive impacts on the demand for animal food products (Rae, 1998). From the above-stated laws and research findings, it is concluded that if strong economic growth and rapid urbanization continued in the future, per capita food expenditures would be expected to continue their upward trend, while per capita food budget shares would be expected to continue their downward trend. In the meanwhile, per capita consumption of food grains would decrease while per capita consumption of high-value foods is expected to increase.

Another potential force driving the change in food demand patterns might be demographic shifts. China has experienced rapid demographic changes due to the population control policies implemented by the government in the 1970s. Typically, population birth rates are almost stagnated while the population is aging. Previous studies have shown that generational differences affect food demand. Hsu, Chern, and Gale (2002) report that, in Japan, seniors consume more rice, fruits, and vegetables, while younger generations consume more beef and beer. Zhong, Xiang, and Zhu (2012) find that changes in sex-age composition have an important impact on per capita energy intake in China. Thus, the changes in age composition related to population aging in China are expected to influence the structure of food demand in the future.

Since the 1980s, particularly since the 21st century, China's per capita incomes have risen sharply along with its accelerated rates of urbanization and of population aging. It is anticipated that per capita income, urbanization, and population aging will continue their upward trend in the future. Thus, the objective of this study is to assess the impacts of income growth, urbanization, and population aging on the structure of food demand for China's urban and rural residents as well as for the population as a whole. In doing so, this study includes the analysis of demand for both at-home and away-from-home foods related to urban and rural residents. More specifically, this study employs a two-step procedure to accomplish the objective. The first step involves estimating a complete demand system, separately for rural and urban residents. A two-stage budgeting framework and pooled provincial and time-series data from 2000 to 2012 is used for this first step estimation.[2] A demand system including food at home (FAH), food away from home (FAFH), and the numeraire good including all goods and services other than foods are estimated in the first stage, while individual commodities within the at-home food group are estimated in the second stage of this first step. The second step involves predicting the food's share of total expenditure, the

[1]All statistical figures in the text are from China Statistical Yearbooks (various issues) of the National Bureau of Statistics of China (NBSC).

[2]Since the fourth quarter of 2012, NBSC has launched its reform on the household survey program to form an integrated survey instead of the two separate urban and rural household surveys. The reform regulates the division of urban and rural areas, integrates the concepts, classifications, and standards, conducts the integrated household survey, and collects household data in the whole country thereafter (China Statistical Yearbook, 2017, p.199). Due to this reform, the provincial data on per capita consumption of various food commodities during 2013–2014 and expenditures on food away from home during 2013–2016 are not available. Moreover, two sets of data on food expenditures and consumption before and after 2013 are no longer fully matched because the standard of the urban and rural division has changed.

proportions of FAFH and of FAH spending to food expenditures, and the composition of at-home food demand separately for the rural residents, the urban residents, and Chinese population as a whole in the year 2030, using the estimated elasticities from the first step.

There have been many studies related to China's food demand, for both urban and rural residents, since the 1980s. These include Lewis and Andrews (1989), Wang and Chern (1992), Fan, Wailes, and Cramer (1995), Gao, Wailes, and Cramer (1996), Huang and Rozelle (1998), Huang and Bouis (2001), Guo, Mroz, Popkin, and Zhai (2000), Gould and Villarreal (2006), Ma, Huang, Fuller, and Rozelle (2006), Min, Fang, and Li (2004), Gale and Huang (2007), Zheng and Henneberry (2010), and Zheng and Zhao (2012). These studies estimate the impact of income, food prices, and demographic variables on demand for foods at home or for foods away from home, either for urban residents or for rural residents, but not for China's population as a whole. In addition, given that urbanization has speeded up in Asian nations, Huang and David (1993) and Rae (1998) estimated the impact of urbanization on food demand for Asian population. The results of these studies indicate that income, urbanization, and demographic characteristics affect food demand in general, but few studies have examined the effect of probable future changes in either income or urbanization or demographic structure on China's food consumption patterns. Differing from previous studies, this study not only estimates urban and rural food demands separately but also combines the demand for foods at home and for foods away from home. Moreover, this study predicts how food demand changes for China's urban and rural residents separately as well as for the population as a whole if per capita income, urbanization, and population aging continue their upward trend into the future. Therefore, the results of this study are expected to better reflect China's current situation and to give a more accurate estimate of future trends in China's food demand patterns.

It is important to understand China's future food demand changes. China has the largest population in the world, accounting for 18.5% of the world total in 2016. Although population control policies starting in the 1970s have decreased birth rates substantially, China's population is projected to reach 1.406 billion in 2030 due to its large population base and population growth inertia. More important, China's urbanization has accelerated since the beginning of this century, with urbanization rates increasing from 36% in 2000 to 57% in 2016. This trend is expected to continue into the future, with the urbanization rate being projected to reach 69% in 2030. Finally, China is in the speeding-up process of population aging. China had 178 million population aged 60 and over, accounting for 13.3% of its total population in 2010. It is anticipated that the aged population is expected to reach 382 million in 2030,[3] suggesting that China will be the nation with the largest number of aged population in the world. It is thus anticipated that income growth, population expansion, urbanization, and population aging would drive changes in the level and composition of food demand in the future. The results of this study can shed some light on future food demand changes and the resulting trade patterns for agricultural products in China.

The remainder of this study is organized as follows. A review on the evolution of food consumption patterns in China is provided. The two-stage almost ideal demand system (AIDS)–quadratic almost ideal demand system (QUAIDS) model and the data used for this study are then described. Next, the estimation procedures and estimated demand elasticities are presented. In the following section, the estimated demand elasticities are used to predict the impact of income growth, urbanization, and population aging on the food demand patterns for 2030 in China. Finally, concluding remarks and policy implications are given.

## 2 | FEATURES AND TRENDS OF FOOD DEMAND IN CHINA

Food consumption patterns for urban residents differ substantially from those for rural residents due to China's dualistic economic structure, a term used by Lewis (1954). Before quantitatively measuring the impact of economic and noneconomic variables on China's rural and urban food demands, a descriptive analysis of food demand is given in the following subsections by examining consumption data over the past two decades. It is noted that this analysis

[3]Figures on population growth come from a forecast from NBSC.

is focused on Chinese food consumption patterns during 2000–2012 instead of 2000–2016 due mainly to a change in the household survey program by the NBSC since 2013.[4]

## 2.1 | Food consumption patterns for urban residents

Urban food consumption patterns have kept changing since the 1990 s, although the change was marginal during 2001–2012. There are various aspects of the change. First, the decline in food share of total expenditures has slowed down. As shown in Table 1, per capita incomes and food expenditures have displayed an accelerating growth trend since 2000. During 1990–2000, real per capita incomes and food expenditures grew at an annual rate of 6.3% and 3.1%, respectively; while the growth rates accelerated to 9.1% and 7.4% per year, respectively, from 2001 to 2012. As per capita, incomes rose rapidly, and food shares of total expenditures declined continuously from 54.2% in 1990 to 36.2% in 2012. Yet, the declines were slower during 2001–2012 than during 1990–2000. The food-expenditure share decreased by 3.0% annually during the former period, while it declined by 0.4% annually during the latter period.

Second, the growth in the shares of expenditures on FAFH in total food expenditures has decelerated. Rising living standards in urban areas are changing the way consumers have their diets. Typically, the share of foods consumed at home as a percentage of total food expenditures has declined, while the share of FAFH in total food expenditure has increased. As shown in Table 1, the shares of FAFH spending increased from 9.1% in 1995 to 21.8% in 2012, suggesting that FAFH spending has become an important component of food expenditures for urban residents. However, the growth in the shares of FAFH spending decelerated over the period of 2001–2012. The shares of FAFH spending grew at an annual rate of 7.9% during 1992–2000, whereas it increased by 2.3% yearly from 2001 to 2012.

Finally, the level and composition of at-home food demand show different features at different periods of time. In the first period (1990–2001), per capita consumption of grains and vegetables decreased dramatically, from 130.7 and 138.7 kg in 1990 to 76.7 and 115.9 kg in 2001, respectively. With the exception of the consumption of pork and beef (and mutton) that declined marginally, per capita consumption of other food items increased considerably during this period. Per capita consumption of milk rose the most at a rate of 9.2% annually, poultry 4.1%, fruits 2.9%, eggs 3.3%, aquatic products 2.7%, and edible oils 2.2%.

In the second period (2002–2012),[5] the composition of foods consumed was relatively unchanged. During this period, per capita consumption of grains kept at about 80 kg, and per capita consumption of vegetables, oils, pork, eggs, and fruits also changed only slightly. In contrast, the per capita consumption of aquatic products, poultry, and beef (and mutton) increased relatively appreciably; whereas per capita consumption of milk rose first and then declined due to the melamine incident occurred in 2008. It is noted that per capita consumption of oils, meats, eggs, aquatic products, milk, and fruits during 2002–2012 was notably more than the consumption during 1990–2000, suggesting the composition of food demand for urban residents is shifting to a dietary structure with more foods with animal origin and fruits while per capita consumption of grains decreasing slowly.

## 2.2 | Food consumption patterns for rural residents

Unlike urban food demand patterns, the food-expenditure shares, FAFH spending shares, and total per capita food consumption for rural residents changed substantially over the period of 2001–2012. First, the decreases in food-expenditure shares accelerated. As shown in Table 1, the annual growth rates in real per capita incomes rose from 6.3% during 1990–2000 to 8.1% during 2001–2012, while the annual growth rates in real food

[4]While the data set during 2013–2016 was no longer fully matched with one before 2013, the trend of changes in food consumption during 2013–2016, in terms of national averages, was generally similar to that from 2000 to 2012. Thus, the findings from this descriptive analysis with the data set during 2000–2012 can be applied to food consumption patterns in China during 2000–2016.

[5]Since 2002 the urban household survey sample has included households registered in an urban area and those who have lived there for at least six months but are registered elsewhere, which means the survey includes both permanent urban households and migrants from rural areas. At the same time, the sample size has also been expanded. As shown in Table 2, per capita quantities consumed are considerably incoherent before and after 2002.

**TABLE 1** Annual per capita income and food consumption patterns, 1990–2012, China

| Year | Per capita income | | Food as % of total expenditures | | Urban food expenditures and composition | | | Rural food expenditures and composition | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Urban (¥)[d] | Rural (¥) | Urban (%) | Rural (%) | Total (¥) | FAH (%)[e] | FAFH (%) | Total (¥) | FAH (%) | FAFH (%) |
| 1990 | 1510 | 686 | 54.2 | 58.8 | 694 | – | – | 344 | 97.7 | 2.3 |
| 1995 | 2213 | 893 | 50.1 | 58.6 | 916 | 90.9 | 9.1 | 435 | – | – |
| 2000 | 2925 | 1184 | 39.4 | 49.1 | 918 | 85.3 | 14.7 | 432 | 92.2 | 7.8 |
| 2001 | 3173 | 1234 | 38.2 | 47.7 | 938 | 84.4 | 15.6 | 433 | – | – |
| 2002 | 3599 | 1296 | 37.7 | 46.2 | 1062 | 81.7 | 18.3 | 444 | – | – |
| 2003 | 3923 | 1351 | 37.1 | 45.6 | 1119 | 81.9 | 18.1 | 457 | – | – |
| 2004 | 4224 | 1444 | 37.7 | 47.2 | 1215 | 80.3 | 19.7 | 507 | – | – |
| 2005 | 4630 | 1566 | 36.7 | 45.5 | 1286 | 79.2 | 20.8 | 559 | 90.4 | 9.6 |
| 2006 | 5113 | 1700 | 35.8 | 43.0 | 1353 | 77.8 | 22.2 | 577 | – | – |
| 2007 | 5735 | 1862 | 36.3 | 43.1 | 1509 | 79.0 | 21.0 | 625 | – | – |
| 2008 | 6217 | 2010 | 37.9 | 43.7 | 1678 | 79.4 | 20.6 | 675 | – | – |
| 2009 | 6828 | 2183 | 36.5 | 41.0 | 1780 | 78.2 | 21.8 | 693 | – | – |
| 2010 | 7361 | 2420 | 35.7 | 41.1 | 1851 | 78.8 | 21.2 | 736 | 86.7 | 13.3 |
| 2011 | 7979 | 2696 | 36.3 | 40.4 | 2015 | 78.5 | 21.5 | 814 | – | – |
| 2012 | 8751 | 2985 | 36.2 | 39.3 | 2152 | 78.2 | 21.8 | 876 | – | – |

*Note*. Per capita incomes and food expenditures for both urban and rural residents are deflated using corresponding consumption price indices (CPI) with 1990 price level as a base. Data on FAFH expenditures for rural residents are from Xu (2011). ¥refers to Chinese Yuan, which is equal to about 6.22 Yuan/US$ in 2015.
Source: China Statistical Yearbooks (various issues). FAH: food at home; FAFH: food away from home.

expenditures increased from 3.0% during the first decade to 6.6% during the second decade. As farmer's incomes rose, the food-expenditure shares declined continuously, from 58.8% in 1990 to 39.3% in 2012. Unlike those in urban areas, food shares in rural areas displayed a rapidly decreasing trend, from an annual average rate of 1.5% during 1990–2000 to 1.7% during 2001–2012 (Table 1).

Second, the growth in the proportion of FAFH spending in total food expenditures accelerated distinctly. As farmers' incomes rose, their food consumption patterns changed. Spending on FAFH has become an important component of food expenditures for rural residents, showing a rapidly increasing trend over the past two decades. While the FAFH spending shares rose at an annual rate of 1.3% during 1990–2000, they increased by 5.5% annually during 2001–2010.

Finally, per capita consumption of at-home grains and vegetables declined while per capita consumption of at-home foods with animal origin rose. As shown in Table 2, with the exceptions of oils, pork, and fruits that changed marginally, per capita consumption of other food items changed considerably during 2001–2012. Per capita consumption of grains and vegetables decreased continuously during this period, with the consumption of grains dropping from 250 kg in 2000 to 166 kg in 2012, an average decline of 34% over a 12-year period; whereas per capita consumption of other foods (including beef and mutton, poultry, eggs, aquatic products, and milk) rose continuously.

Preliminary findings can be drawn from comparing the food demand patterns between urban and rural residents. First, rural food demand pattern differs substantially from the urban pattern. As compared to urban residents, rural per capita consumption of grains is substantially higher, while rural consumption of other food items is considerably lower. In particular, per capita consumption of foods with animal origin and fruits of rural residents is substantially lower than that of urban residents. The difference reflects lower incomes and more self-produced foods in rural areas, as well as less eating out in restaurants and fewer purchases of processed foods (Hsu et al., 2002). Therefore, an upgrade in Chinese food demand patterns will depend on the rise in rural residents'

**TABLE 2** Annual per capita food consumption, 1990–2012, China (kilogram/person)

| Year | Grains | Vegetables | Oils | Pork | Beef | Poultry | Eggs | Fish | Milk | Fruits |
|---|---|---|---|---|---|---|---|---|---|---|
| Urban | | | | | | | | | | |
| 1990 | 130.7 | 138.7 | 6.4 | 18.5 | 3.3 | 3.4 | 7.3 | 7.7 | 4.6 | 41.1 |
| 1995 | 97.0 | 116.5 | 7.1 | 17.2 | 2.4 | 4.0 | 9.7 | 9.2 | 4.6 | 45.0 |
| 2000 | 82.3 | 114.7 | 8.2 | 16.7 | 3.3 | 5.4 | 11.2 | 11.7 | 9.9 | 57.5 |
| 2001 | 76.7 | 115.9 | 8.1 | 16.0 | 3.2 | 5.3 | 10.4 | 10.3 | 11.9 | 56.5 |
| 2002 | 79.5 | 116.5 | 8.5 | 20.3 | 3.0 | 9.2 | 10.6 | 13.2 | 15.7 | 56.6 |
| 2003 | 79.5 | 118.3 | 9.2 | 20.4 | 3.3 | 9.2 | 11.2 | 13.4 | 18.6 | 57.8 |
| 2004 | 78.2 | 122.3 | 9.3 | 19.2 | 3.7 | 6.4 | 10.4 | 12.5 | 18.8 | 56.5 |
| 2005 | 77.0 | 118.6 | 9.3 | 20.2 | 3.7 | 9.0 | 10.4 | 13.0 | 18.3 | 60.2 |
| 2006 | 75.9 | 117.6 | 9.4 | 20.0 | 3.8 | 8.3 | 10.4 | 13.0 | 18.3 | 60.2 |
| 2007 | 77.6 | 117.8 | 9.6 | 18.2 | 3.9 | 9.7 | 10.3 | 14.2 | 17.8 | 59.5 |
| 2008 | 80.8 | 123.2 | 10.3 | 19.3 | 3.4 | 10.1 | 10.7 | 14.8 | 15.2 | 54.5 |
| 2009 | 81.4 | 120.5 | 9.7 | 20.5 | 3.7 | 10.5 | 10.6 | 15.4 | 14.9 | 56.6 |
| 2010 | 81.5 | 116.1 | 8.8 | 20.7 | 3.8 | 10.2 | 10.0 | 15.2 | 14.0 | 54.2 |
| 2011 | 80.7 | 114.6 | 9.3 | 20.6 | 3.9 | 10.6 | 10.1 | 14.6 | 13.7 | 52.0 |
| 2012 | 78.8 | 112.3 | 9.1 | 21.2 | 3.7 | 10.8 | 10.5 | 15.2 | 14.0 | 56.1 |
| Rural | | | | | | | | | | |
| 1990 | 262.1 | 134.0 | 5.2 | 10.5 | 0.8 | 1.3 | 2.4 | 2.1 | 1.1 | 6.8 |
| 1995 | 256.1 | 104.6 | 5.9 | 10.6 | 0.7 | 1.8 | 3.2 | 3.4 | 0.6 | 13.0 |
| 2000 | 250.2 | 106.7 | 7.1 | 13.3 | 1.1 | 2.8 | 4.8 | 3.9 | 1.1 | 18.3 |
| 2001 | 238.6 | 109.3 | 7.0 | 13.4 | 1.2 | 2.9 | 4.7 | 4.1 | 1.2 | 20.3 |
| 2002 | 236.5 | 110.6 | 7.6 | 13.7 | 1.2 | 2.9 | 4.7 | 4.4 | 1.2 | 18.8 |
| 2003 | 222.4 | 107.4 | 6.3 | 13.8 | 1.3 | 3.2 | 4.8 | 4.7 | 1.7 | 17.5 |
| 2004 | 218.3 | 106.6 | 5.3 | 13.5 | 1.3 | 3.1 | 4.6 | 4.5 | 2.0 | 17.0 |
| 2005 | 208.9 | 102.3 | 6.0 | 15.6 | 1.5 | 3.7 | 4.7 | 4.9 | 2.9 | 17.2 |
| 2006 | 205.6 | 100.5 | 5.8 | 15.5 | 1.6 | 3.5 | 5.0 | 5.0 | 3.1 | 19.1 |
| 2007 | 199.5 | 99.0 | 6.0 | 13.4 | 1.5 | 3.9 | 4.7 | 5.4 | 3.5 | 19.4 |
| 2008 | 199.1 | 99.7 | 6.3 | 12.6 | 1.3 | 4.4 | 5.4 | 5.2 | 3.4 | 19.4 |
| 2009 | 189.3 | 98.4 | 6.2 | 14.0 | 1.3 | 4.2 | 5.3 | 5.3 | 3.6 | 20.5 |
| 2010 | 181.4 | 93.3 | 6.3 | 14.4 | 1.4 | 4.2 | 5.1 | 5.2 | 3.6 | 19.6 |
| 2011 | 170.7 | 89.4 | 6.6 | 14.4 | 1.9 | 4.5 | 5.4 | 5.4 | 5.2 | 21.3 |
| 2012 | 165.5 | 84.7 | 6.9 | 14.4 | 1.9 | 4.5 | 5.9 | 5.4 | 5.3 | 22.8 |

*Note.* Beef refers to beef and mutton, and fishes denote aquatic products.
Source: *China Statistical Yearbook* (various years).

incomes and rapid urbanization. Second, the composition of demand for FAFH differs from that of at-home foods. More specifically, the former includes more of meats, aquatic products, and vegetables and less of grains and fruits as compared to the latter (Bai, Wahl, Seale, & Lohmar, 2012; Ma et al., 2006). The rise in spending shares of FAFH as well as the changes in composition of demand for at-home food over the past two decades suggest that, as China's economy continues its growth while its urbanization speeds up in the future, per capita consumption of food grains is expected to further decline while per capita consumption of foods with animal origin and fruits to further rise.

## 3 | A TWO-STAGE AIDS–QUAIDS MODEL

Assuming that preferences are weakly separable and the group price indices being used do not vary too greatly with subutility level,[6] a two-stage budgeting procedure is used to characterize consumer preferences for foods in China. In the first stage, the consumer allocates expenditures to foods at home, foods away from home, and the numeraire good. In the second stage, the consumer chooses food commodities conditional on total FAH expenditure.

This study chooses the AIDS of Deaton and Muellbauer (1980a) in the first stage and the QUAIDS of Banks, Blundell, and Lewbel (1997) in the second stage. The QUAIDS functional form is as follows:

$$w_{it} = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln(p_{jt}) + \beta_i \ln\left[\frac{x_t}{a(p_t)}\right] + \frac{\lambda_i}{b(p_t)}\left\{\ln\left[\frac{x_t}{a(p_t)}\right]\right\}^2 + u_{it}, \tag{1}$$

where $i$ and $j$ indicate goods, and $n$ denotes the number of goods included in the demand system; $w_{it}$ is the share of spending on good $i$ in year$t$; $p_{jt}$ indicates price of good $j$ in year $t$; $x_t$ is the total expenditure on the $n$ goods in the system in year $t$; $\alpha_i$, $\gamma_{ij}$, $\beta_i$, and $\lambda_i$ are parameters; $u_{it}$ is error term; $a(p_t)$ and $b(p_t)$ are price indices and defined as follows:

$$\ln a(p_t) = \alpha_0 + \sum_{j}^{n} \alpha_j \ln(p_{jt}) + 0.5 \sum_{i}^{n} \sum_{j}^{n} \gamma_{ij} \ln(p_{it}) \ln(p_{jt}) \tag{2a}$$

$$b(p_t) = \prod_{i=1}^{n} p_{it}^{\beta_i}. \tag{2b}$$

Demographic variables for age composition, including the proportion of seniors aged 65 and over and of children aged 0–14 to total population, are translated into the intercept terms in the QUAIDS models.[7] As shown in the study of Huang and Rozelle (1998), the market development in rural China has played an important role shaping food demand pattern for rural residents. The market development index is measured as the portion of the total value of consumed food products which were purchased by a household on the market (as opposed to be self-produced) and, accordingly, this variable is added in the intercept terms of QUAIDS model only for rural residents.

Thus, the intercept term $\alpha_i$ in the QUAIDS models becomes as $\alpha_i = \alpha_{i0} + \sum_{k=1}^{l} \alpha_{ik} Z_k$, where $\alpha_{i0}$ and $\alpha_{ik}$ are parameters that are estimated, and $Z_k$ denotes a total of $l$ demographic variables and market development index.

The properties of demand from the neoclassical theory can be imposed on the QUAIDS model by restricting its parameters. The adding-up restriction is given by

$$\sum_{i=1}^{n} \alpha_{i0} = 1,\ \sum_{i=1}^{n} \alpha_{ik} = 0,\ \sum_{i=1}^{n} \gamma_{ij} = 0,\ \sum_{i=1}^{n} \beta_i = 0,\ \sum_{i=1}^{n} \lambda_i = 0. \tag{3a}$$

Homogeneity is imposed as

$$\sum_{j=1}^{n} \gamma_{ij} = 0 \tag{3b}$$

[6]According to Deaton and Muellbauer (1980b), if preferences are weakly separable and the group price indices being used do not vary too greatly with sub-utility level, two-stage budgeting will lead to an approximately correct allocation. The assumption suggests that the variation of group true cost-of-living price indices with sub-utility is not very great so that the indices involved in the first stage can be approximated by Paasche or Laspeyres indices, which are exactly the same as the indices that are used when demand systems are estimated for aggregated groups at the first stage.

[7]Since variables on sex composition are not statistically significant due to very marginal changes over the studied period, they are not included in this analysis.

and Slutsky symmetry is given by

$$\gamma_{ij} = \gamma_{ji}, \quad i \neq j. \tag{3c}$$

The price and expenditure elasticities of demand are calculated from the estimated parameters of the QUAIDS model following Banks et al. (1997). The uncompensated (Marshallian) price elasticities are denoted by

$$e_{ij} = w_i^{-1}\left\{\gamma_{ij} - \left(\beta_i + \frac{2\lambda_i}{b(p)}\right)\left[\ln\left(\frac{x}{a(p)}\right)\right]\left(\alpha_j + \sum_k^n \gamma_{jk}\ln(p_k)\right) - \frac{\lambda_i\beta_j}{b(p)}\left[\ln\left(\frac{x}{a(p)}\right)\right]^2\right\} - \delta_{ij}, \tag{4}$$

where $\delta_{ij}$ is the Kronecker delta, which is equal to 1 when $i = j$, otherwise $\delta_{ij} = 0$.

The food-expenditure elasticities are calculated as:

$$e_i = 1 + w_i^{-1}\left[\beta_i + \frac{2\lambda_i}{b(p)}\ln\left(\frac{x}{a(p)}\right)\right]. \tag{5}$$

The demand elasticities with respect to demographic variables and market development index are derived as:

$$e_{ik}^z = \left\{\alpha_{ik} - \sum_k^n \alpha_k \ln(p_k)\left[\beta_i + \frac{2\lambda_i}{b(p)}\ln\left(\frac{x}{a(p)}\right)\right]\right\} \times \left(\frac{Z_k}{w_i}\right) \tag{6}$$

The AIDS model is nested within the QUAIDS model. The equation (1) without the last expenditure term on the right-hand side, that is if $\lambda_i = 0$ for all $i$, is the AIDS functional form. The Marshallian price, expenditure, and noneconomic variable elasticity formulae derived from the QUAIDS model become the same as those derived from the AIDS model when $\lambda_i$ equals zero. Note that the AIDS model in the first stage covers FAH, FAFH, and the numeraire good for urban residents while consisting either of FAH and the numeraire good in a system or of FAFH and the numeraire good in a system for rural residents due to data limitation (see Data section).

Based on Edgerton (1997), the income (unconditional expenditure) and unconditional uncompensated price elasticities of demand for food commodities in the second stage are computed as

$$\eta_i = e_i \cdot e_f \tag{7}$$

$$\eta_{ij} = e_{ij} + e_i w_j (1 + e_{ff}), \tag{8}$$

where $\eta_i$ denotes income elasticity of demand for the $i$th commodity, $e_i$ is at-home food-expenditure elasticity of demand for the $i$th commodity, $e_f$ represents income elasticity of demand for at-home foods, $\eta_{ij}$ denotes unconditional price elasticity of demand for commodity $i$ with respect to the price of commodity $j$, $e_{ij}$ is conditional price elasticity of demand commodity $i$ with respect to the price of commodity $j$, $e_{ff}$ denotes the own-price elasticity of demand for at-home foods, and $w_j$ represents the share of at-home food spending on good $j$.

## 4 | DATA SOURCES AND EXPLANATIONS

Urban demand analysis is conducted using pooled time-series and cross-provincial data (provincial cell means), covering 31 provinces, from 2000 to 2012. There are three commodity groups in the first stage, namely FAH, FAFH, and the numeraire good. Data on expenditure and price index for FAFH as well as total expenditure and consumer price index (CPI) for urban residents come from *China Statistical Yearbook* (2001–2013) published by NBSC. The expenditure data for FAH are the total of expenditures on 10 individual commodities included in the second stage, while the price indexes for FAH are Laspeyres indices calculated from Stone's price indices for the

10 individual commodity prices. The price index for the numeraire good is obtained by solving $\ln(\text{CPI}) = \sum_{g=1}^{3} \tilde{w}_g \ln(p_g)$ (Wohlgenant, 1989; Zhen, Brissette, & Ruff, 2014), where $g$ represents FAH, FAFH, and the numeraire good, respectively, and $\tilde{w}_g$ is the mean of the share that is used to avoid possible endogenous problem if the current share $w_g$ is used (Moschini, 1995).

The 10 major at-home food commodities in the second stage for urban residents consist of grains, beans (including soybean, other beans, and tofu), oils and fats, meats (including pork, beef, and mutton), poultry (meat), eggs, aquatic products, vegetables, fruits, and dairy products (including milk, milk powder, and yogurt). Expenditure data for the 10 commodities during 2000–2012 come from *China Urban Life and Price Yearbook* (2001–2013) published by NBSC. Price data are from various sources. Except for Heilongjiang, Anhui, and Hebei provinces, data on food consumption for other 28 provinces during 2000–2009 come from provincial statistical yearbooks (2001–2010) published by respective provincial statistical bureaus, while price data for the 28 provinces are unit values calculated with expenditure and quantities. Price data for Heilongjiang, Anhui, and Hebei provinces during 2000–2009 come from *China Yearbook of Agricultural Price Survey* (2004–2010) published by NBSC. All prices on the 10 commodities during 2010–2012 are extrapolated from data in 2009 and the corresponding urban price indexes on various foods from *China Urban Life and Price Yearbook* (2001–2013).

Rural demand analysis is carried out using pooled time-series and cross-provincial data, covering 30 provinces (not including Tibet) during 2000–2012. There are three commodity groups in the first stage: FAH, FAFH, and the numeraire good. Data on expenditure and price index for FAFH from eight provinces, including Jilin, Jiangsu, Zhejiang, Shandong, Hubei, Guangdong, Shaanxi, and Gansu, are from their respective provincial statistical yearbooks (2001–2013).[8] Rural total expenditure and CPI for the 30 provinces come from *China Statistical Yearbook* (2001–2013) and *China Rural Statistical Yearbook* (2001–2013) published by NBSC. Similar to the data for urban residents, the expenditure data on FAH are the total of expenditures on 10 individual commodities in the second stage; while the price indexes for FAH are Laspeyres indices calculated from Stone's price indices for the 10 individual commodity prices. Since the data on FAFH are only for eight provinces while FAH data are for 30 provinces, the demand systems for FAH and for FAFH are estimated separately. The price index for the numeraire good in AIDS model including FAFH and the numeraire good is derived from $\ln(\text{CPI}) = \tilde{w}_o \ln(p_o) + \tilde{w}_n \ln(p_n)$, while the price index for the numeraire good in the AIDS model including FAH and the numeraire good is derived from $\ln(CPI) = \tilde{w}_f \ln(p_f) + \tilde{w}_n \ln(p_n)$, where $f$, $o$, and $n$ stand for FAH, FAFH, and the numeraire good, respectively.

The ten food categories that are included in the second stage for rural residents are grains, oils and fats, pork, beef (including beef and mutton), poultry (meat), eggs, aquatic products, vegetables, fruits, and dairy products. Quantity data for the 10 commodities during 2000–2012 come from *China Yearbook of Rural Household Survey* (2001–2013) published by NBSC. Price data for grains, vegetables, oils and fats, poultry, aquatic products, and fruits during 2000–2010 are calculated based on farmer's market price data in 2010 from *China Yearbook of Agricultural Price Survey* (2011) and the rural consumer price indices for various foods from *China Urban Life and Price Yearbook* (2001–2013). Price data for pork, beef, and eggs during 2000–2010 are from *China Animal Husbandry Yearbook* (2001–2011) published by China Ministry of Agriculture (MoA). Price data for dairy products during 2000–2009 are weighted average between the procurement prices for fresh milk from *China Dairy Industry Yearbook* (2001–2011) published by MoA and the market prices for dairy products for urban residents, while the prices during 2010–2012 are extrapolated with 2009 prices and the corresponding rural CPI on dairy products. All prices on other nine commodities during 2011–2012 are derived from data in 2010 and the corresponding rural

[8]Because of unavailability of data on FAFH expenditures from 30 provinces, the demand for FAFH for rural residents is estimated using the data from eight provinces instead. A comparison of FAFH spending in 2000 shows that the national average is slightly lower than the average derived from the eight provinces. Given the fact that the eight provinces are from various regions with different income levels, the data from these provinces can be used to approximate the national average on FAFH spending.

price indexes on various foods. Finally, expenditure data for the 10 commodities are computed as the product of per capita consumption and prices.[9]

Demographic variables including the proportion of seniors aged 65 and over and of children aged 0–14 to total population for both urban and rural residents are from *China Population and Employment Statistical Yearbooks* (2001–2013) by NBSC, while the market development index is from *China Yearbook of Rural Household Survey* (2001–2013).

## 5 | ESTIMATION PROCEDURES AND RESULTS

### 5.1 | Estimation procedures

The two-stage AIDS and QUAIDS models are estimated in the form of a two-way fixed effects model (regional effect and time effects). Specifically, assuming that residents in the provinces within the same group have roughly similar preference, all provinces are grouped into 5 groupings via a cluster analysis. The period from 2000 to 2012 is divided into 5 periods in chronological order. The four regional dummies and four-time dummies are then incorporated into the intercept terms of the AIDS and QUAIDS models. Using a two-way fixed effects model can not only account for regional differences and dynamic changes in consumer preference to obtain consistent estimates but also ensure sufficient degrees of freedom for accurate estimation.

Heteroskedasticity and first-order autocorrelation are tested at the first and second stages of the demand systems. The null hypothesis of homoskedasticity is rejected at the 5% significance level only for the AIDS model on FAH for rural residents, while the null hypothesis of no first-order autocorrelation is rejected at the 5% significance level for all models in the estimation. Accordingly, a vector autoregression proposed by Moschini and Moro (1994) is embedded into the AIDS and QUAIDS models to eliminate the serial autocorrelation problems inherent in the models. The AIDS model on FAH for the rural residents is estimated using White's heteroskedasticity consistent estimator to correct standard errors of parameters, while the AIDS models for FAFH and the QUAIDS models for both urban and rural residents are estimated separately using iterative seemingly unrelated regression method. All the models are estimated with homogeneity and symmetry imposed. Since the adding-up structure for a complete set of expenditure shares is inherent in the AIDS and QUAIDS models, the full system including all equations will be singular. Following the standard convention, the numeraire good equation in the AIDS models, the "beans" equation in the QUAIDS model for the urban residents, and the "fruits" equation in the QUAIDS model for the rural residents are dropped from estimation. Price and expenditure elasticities for beans for urban residents as well as for fruits for rural residents are calculated using the adding-up restrictions (Yen, Kan, & Su, 2002) (for the coefficient estimates see Tables A1–A2).

### 5.2 | Empirical results

The Marshallian own-price and income elasticities of demand as well as demand elasticities with respect to demographic variables and market development index for both urban and rural residents in the first stage are reported in Table 3. All own-price and income elasticities and the demand elasticities with respect to market

[9]The official statistics on food consumption for rural residents are underestimated as a declining trend of per capita caloric intake has been observed. While Carter, Zhong, and Zhu (2012) and Zhong et al. (2012) indicate that the changing age structure of rural residents is the cause of decrease in per capita caloric intake; Yu and Abler (2016) argue that measurement errors in household size in which off-farm migrant workers are wrongly included as family members lead to the data bias. However, according to NBSC that household members who live in the household for less than 6 months are not included in either urban or rural household survey, the decline in per capita caloric intake are due mainly to the omission of migrant workers in the official household surveys. Li (2018), based on a sample survey of 7,505 migrant workers, finds that per capita consumption of grain and meats for migrant workers is 38% and 63%, respectively, higher than the official statistics for rural residents. While the official statistics for rural residents would be logical if off-farm migrant workers are not treated as rural residents, the official statistics for Chinese population as a whole might be biased because food consumption patterns for the 270 million migrant workers are not captured. Since we use demand elasticities for FAH and for FAFH to reveal food consumption patterns, specific consumption of commodities might not in a significant way affect our conclusions.

**TABLE 3** Estimated demand elasticities for foods, Step I, Stage I, time-series (2000–2012) and cross-provincial (31 provinces for urban residents as well as 30 and 8 provinces for rural residents for FAH and FAFH, respectively)

| Item | Income elasticities | Own-price elasticities | Aged 0–14 | Aged 65 and over | Market development |
|---|---|---|---|---|---|
| Urban residents | | | | | |
| FAFH | 1.039** | −0.755** | −0.082 | 0.012 | |
| | (0.051) | (0.155) | (0.054) | (0.029) | |
| FAH | 0.613** | −0.584** | −0.029 | −0.022 | |
| | (0.026) | (0.045) | (0.029) | (0.015) | |
| Rural residents | | | | | |
| FAFH | 0.927** | −0.952** | −0.161 | 0.225 | 2.486** |
| | (0.152) | (0.378) | (0.103) | (0.458) | (0.369) |
| FAH | 0.806** | −0.756** | 0.027 | −0.031 | −0.408** |
| | (0.074) | (0.061) | (0.054) | (0.069) | (0.199) |

*Note*. Numbers in parentheses are standard errors. Double asterisks (**) indicate significance at the 5% level. FAH: food at home; FAFH: food away from home.

development index are statistically significant at the 5% level, while all demand elasticities with respect to demographic variables are not statistically significant at the 10% level.

The conditional Marshallian price and food-expenditure elasticities of demand for at-home food commodities as well as at-home food demand elasticities with respect to demographic variables and market development index in the second stage for urban and rural residents, respectively, are presented in Tables 4 and 5. For urban residents (Table 4), all own-price and food-expenditure elasticities are statistically significant at the 5% level, while more than 64% of cross-price elasticities are statistically significant at the 5% level. For rural residents (Table 5), with the exception of the own-price elasticity for beef and mutton that is statistically significant at the 10% level, all other own-price and food-expenditure elasticities are at the 5% significance level; while close to 50% of cross-price elasticity estimates are statistically significant at the 5% level. For urban and rural residents, there are 35% and 45% of demand elasticities with respect to demographic variables that are statistically significant at the 10% level, respectively; whereas most of the demand elasticities with respect to market development index are significant at the 5% level (for the conditional compensated price elasticities see Tables A3–A4).

The unconditional Marshallian price and income elasticities for urban and rural residents are reported in Tables 6 and 7, respectively.[10] All income elasticities of demand for at-home food commodities are positive and statistically significant at the 5% level. With the exception of the own-price elasticities for oils and fats and beef and mutton for rural residents that are statistically significant at the 10% level, all other unconditional own-price elasticities are negative and statistically significant at the 5% level. Finally, most of unconditional cross-price elasticities are statistically significant at the conventional level.

Because in this study the main objective is to understand the relationships between income and food demand as well as between demographic variables and food demand, elaboration is given on income and demographic elasticities for FAH, FAFH, and commodities within FAH. The income elasticities of FAH for urban and rural residents are 0.613 and 0.806, respectively; while those of FAFH for urban and rural residents are 1.039 and 0.927, respectively (Table 3). The income elasticity of FAFH for urban residents is slightly lower from this study than those from Min et al. (2004), Ma et al. (2006), and Zheng and Zhao (2012); while it can be still classified as a luxury good similar to those from these previous studies. The relative lower elasticity of FAFH for rural residents as compared with that for urban residents appears to be contradictory to the conventional knowledge and Engel's law. Given that rural residents in China have nonsteady income sources and low level of medical insurance and pensions, the

[10]According to Bohrnstedt and Goldberger (1969), if $x$ and $y$ are uncorrelated while $x$ and $y$ are the expectation and variance independent, then $\mathrm{Var}(xy) = E^2(x)\mathrm{Var}(y) + E^2(y)\mathrm{Var}(x) + \mathrm{Var}(x)\mathrm{Var}(y)$. This method is thus used for calculating the standard errors of all income elasticities. The standard errors of unconditional price elasticities are computed with delta methods.

**TABLE 4** Demand elasticities for food commodities, urban China, Step I, Stage II, food-at-home, time-series (2000–2012) and cross-provincial (31 provinces)

| Food items | Grains | Beans | Oils and fats | Meats | Poultry | Eggs | Aquatic prod. | Vegetable. | Fruits | Dairy prod. |
|---|---|---|---|---|---|---|---|---|---|---|
| *Conditional Marshallian price elasticities* | | | | | | | | | | |
| Grains | **−0.412*** | −0.047* | −0.016 | 0.028 | −0.105* | −0.016 | 0.007 | −0.014 | 0.009 | −0.031 |
| | (0.064) | (0.015) | (0.027) | (0.040) | (0.038) | (0.021) | (0.047) | (0.032) | (0.036) | (0.044) |
| Beans | −0.313* | **−0.195*** | −0.216* | 0.262* | −0.402* | 0.033 | −0.225* | 0.160* | 0.188* | 0.039 |
| | (0.110) | (0.091) | (0.066) | (0.079) | (0.074) | (0.076) | (0.085) | (0.055) | (0.066) | (0.078) |
| Oils and fats | −0.021 | −0.086* | **−0.406*** | 0.339* | 0.155* | −0.057† | −0.168* | −0.066 | −0.078 | −0.120* |
| | (0.078) | (0.026) | (0.063) | (0.0690 | (0.060) | (0.034) | (0.073) | (0.050) | (0.057) | (0.068) |
| Meats | −0.040† | 0.016* | 0.047* | **−0.834*** | 0.107* | 0.031* | 0.009 | −0.028 | −0.040* | −0.160* |
| | (0.023) | (0.006) | (0.014) | (0.031) | (0.020) | (0.009) | (0.022) | (0.017) | (0.019) | (0.020) |
| Poultry | −0.233* | −0.108* | 0.079* | 0.274* | **−0.769*** | −0.061* | −0.532* | −0.120* | 0.092† | 0.310* |
| | (0.072) | (0.019) | (0.0390 | (0.0680 | (0.081) | (0.027) | (0.067) | (0.050) | (0.055) | (0.063) |
| Eggs | −0.086 | 0.014 | −0.093* | 0.211* | −0.120* | **−0.961*** | 0.016 | 0.025 | −0.160* | 0.291* |
| | (0.081) | (0.041) | (0.047) | (0.062) | (0.056) | (0.070) | (0.066) | (0.043) | (0.051) | (0.058) |
| Aquatic p. | −0.141* | −0.065* | −0.146* | −0.231* | −0.512* | −0.022 | **−0.777*** | −0.060 | −0.185* | 0.331* |
| | (0.078) | (0.019) | (0.042) | (0.065) | (0.059) | (0.027) | (0.098) | (0.052) | (0.055) | (0.070) |
| Vegetables | −0.057* | 0.015* | −0.042* | −0.047† | −0.052* | 0.003 | 0.037 | **−0.824*** | 0.103* | −0.079* |
| | (0.029) | (0.007) | (0.016) | (0.0280 | (0.024) | (0.010) | (0.028) | (0.030) | (0.024) | (0.030) |
| Fruits | −0.051 | 0.024* | −0.059* | −0.105* | 0.066† | −0.055* | −0.061 | 0.125* | **−0.937*** | 0.044 |
| | (0.045) | (0.011) | (0.025) | (0.043) | (0.036) | (0.016) | (0.041) | (0.033) | (0.047) | (0.040) |
| Dairy p. | −0.215* | −0.005 | −0.137* | −0.704* | 0.295* | 0.116* | 0.437* | −0.269* | −0.010 | **−1.145*** |
| | (0.089) | (0.022) | (0.047) | (0.073) | (0.066) | (0.029) | (0.085) | (0.068) | (0.066) | (0.119) |
| *Food-expenditure elasticities* | | | | | | | | | | |
| | 0.597* | 0.669* | 0.507* | 0.892* | 1.068* | 0.864* | 1.809* | 0.943* | 1.010* | 1.638* |
| | (0.060) | (0.094) | (0.092) | (0.0420 | (0.099) | (0.075) | (0.104) | (0.050) | (0.070) | (0.125) |
| *Demographic elasticities* | | | | | | | | | | |
| u014 | −0.008 | 0.238* | 0.109* | 0.032 | 0.087 | 0.060 | 0.171 | −0.106* | −0.107* | 0.057 |
| | (0.034) | (0.096) | (0.053) | (0.020) | (0.094) | (0.060) | (0.159) | (0.032) | (0.032) | (0.076) |
| u65 | −0.050* | 0.007 | 0.031 | −0.020† | 0.055 | −0.047 | 0.187* | 0.027 | −0.002 | −0.002 |
| | (0.019) | (0.054) | (0.030) | (0.012) | (0.054) | (0.034) | (0.090) | (0.019) | (0.018) | (0.043) |

*Note.* Numbers in parentheses are standard errors. "*" and "†" indicate significance at the 5% and 10 levels, respectively. u014 and u65 stand for the variables on the proportion of children aged 0–14 and of seniors 65 and over in urban China, respectively.

**TABLE 5** Demand elasticities for food commodities, rural China, Step I, Stage II, food-at-home, time-series (2000–2012) and cross-provincial (30 provinces)

| Food items | Grains | Vegetable | Oils and fats | Pork | Beef | Poultry | Eggs | Dairy prod. | Aquatic prod. | Fruits |
|---|---|---|---|---|---|---|---|---|---|---|
| *Conditional Marshallian price elasticities* | | | | | | | | | | |
| Grains | **−0.486*** | −0.102* | −0.081* | 0.022 | −0.093* | 0.052* | 0.035* | 0.043* | 0.096* | 0.032 |
| | (0.055) | (0.033) | (0.024) | (0.030) | (0.026) | (0.022) | (0.013) | (0.010) | (0.026) | (0.030) |
| Vegetables | −0.355* | **−0.464*** | −0.075* | −0.185* | −0.027 | −0.069* | −0.041* | −0.044* | −0.064* | −0.069* |
| | (0.040) | (0.048) | (0.023) | (0.034) | (0.028) | (0.021) | (0.011) | (0.010) | (0.026) | (0.029) |
| Oils and fats | −0.522* | −0.217* | **−0.240*** | −0.143 | 0.012 | 0.016 | 0.108* | 0.085* | 0.102 | −0.186* |
| | (0.124) | (0.096) | (0.115) | (0.100) | (0.083) | (0.074) | (0.046) | (0.029) | (0.091) | (0.093) |
| Pork | −0.105* | −0.132* | −0.046 | **−0.520*** | −0.053 | −0.023 | 0.020 | −0.017 | −0.033 | −0.014 |
| | (0.052) | (0.047) | (0.034) | (0.057) | (0.036) | (0.028) | (0.016) | (0.013) | (0.032) | (0.037) |
| Beef | −1.122* | −0.394 | −0.039 | −0.501* | **−0.399**† | 0.201 | −0.022 | 0.017 | −0.170 | 0.091 |
| | (0.221) | (0.197) | (0.138) | (0.178) | (0.217) | (0.123) | (0.0630 | (0.055) | (0.129) | (0.163) |
| Poultry | −0.078 | −0.269* | −0.005 | −0.207* | 0.236* | **−0.300*** | −0.136* | −0.257* | −0.220* | −0.307* |
| | (0.135) | (0.104) | (0.090) | (0.102) | (0.091) | (0.113) | (0.054) | (0.032) | (0.100) | (0.102) |
| Eggs | 0.213 | −0.223* | 0.228* | 0.119 | 0.027 | −0.195* | **−1.083*** | 0.094* | 0.123 | −0.259* |
| | (0.149) | (0.089) | (0.098) | (0.096) | (0.080) | (0.093) | (0.126) | (0.028) | (0.119) | (0.099) |
| Dairy p. | 0.444* | −0.359* | 0.252* | −0.152 | 0.096 | −0.561* | 0.133* | **−0.832*** | 0.126 | −0.057 |
| | (0.142) | (0.130) | (0.083) | (0.116) | (0.096) | (0.076) | (0.038) | (0.053) | (0.095) | (0.099) |
| Aquatic p. | 0.194 | −0.085 | 0.144 | −0.202 | 0.003 | −0.182 | 0.080 | 0.055 | **−0.855*** | −0.229 |
| | (0.208) | (0.138) | (0.134) | (0.133) | (0.111) | (0.115) | (0.084) | (0.045) | (0.206) | (0.144) |
| Fruits | −0.036 | −0.137 | −0.149* | −0.058 | 0.087 | −0.173* | −0.099* | −0.019 | −0.128† | **−0.367*** |
| | (0.117) | (0.094) | (0.072) | (0.085) | (0.076) | (0.065) | (0.036) | (0.026) | (0.076) | (0.116) |
| *Food-expenditure elasticities* | | | | | | | | | | |
| | 0.483* | 1.393* | 0.985* | 0.924* | 2.338* | 1.542* | 0.956* | 0.910* | 1.077* | 1.078* |
| | (0.052) | (0.068) | (0.132) | (0.085) | (0.290) | (0.147) | (0.131) | (0.237) | (0.204) | (0.138) |
| *Demographic elasticities* | | | | | | | | | | |
| r014 | 0.086* | 0.053 | 0.195* | −0.115* | −0.495* | 0.137† | −0.256* | −0.610* | −0.015 | 0.132† |
| | (0.044) | (0.044) | (0.081) | (0.052) | (0.196) | (0.078) | (0.075) | (0.134) | (0.029) | (0.071) |

(Continues)

**TABLE 5** (Continued)

| Food items | Grains | Vegetable | Oils and fats | Pork | Beef | Poultry | Eggs | Dairy prod. | Aquatic prod. | Fruits |
|---|---|---|---|---|---|---|---|---|---|---|
| r65 | −0.001 | −0.051 | 0.167 | −0.092 | −0.250 | 0.140 | 0.391* | 0.179 | 0.053 | −0.024 |
| | (0.066) | (0.066) | (0.119) | (0.078) | (0.294) | (0.114) | (0.105) | (0.201) | (0.042) | (0.105) |
| Market | −1.350* | 0.065 | 1.004* | −0.724* | 0.631 | 0.269 | 1.342* | 1.788* | 0.659* | 1.386* |
| | (0.137) | (0.137) | (0.253) | (0.161) | (0.625) | (0.250) | (0.240) | (0.424) | (0.092) | (0.224) |

*Note*. Numbers in parentheses are standard errors. "*" and "†" indicate significance at the 5% and 10 levels, respectively. r014 and r65 stand for the variables on the proportion of children aged 0–14 and of seniors 65 and over in rural China, respectively. Market represents market development index.

**TABLE 6** Unconditional price and income elasticities for food commodities consumed at home, urban China, time-series (2000–2012), and cross-provincial (31 provinces)

| Food items | Grains | Beans | Oils and fats | Meats | Poultry | Eggs | Aquatic prod. | Vegetable. | Fruits | Dairy prod. |
|---|---|---|---|---|---|---|---|---|---|---|
| *Unconditional Marshallian price elasticities* | | | | | | | | | | |
| Grains | −0.377* | −0.042* | −0.003 | 0.085* | −0.085* | −0.007 | 0.029 | 0.025 | 0.039 | −0.012 |
| | (0.065) | (0.015) | (0.027) | (0.044) | (0.038) | (0.021) | (0.047) | (0.034) | (0.037) | (0.044) |
| Beans | −0.274* | −0.189* | −0.202* | 0.326* | −0.380* | 0.043 | −0.200* | 0.204* | 0.221* | 0.060 |
| | (0.111) | (0.091) | (0.066) | (0.083) | (0.075) | (0.076) | (0.086) | (0.057) | (0.067) | (0.078) |
| Oils and fats | 0.008 | −0.082* | −0.395* | 0.388* | 0.172* | −0.049 | −0.149* | −0.033 | −0.053 | −0.104 |
| | (0.079) | (0.026) | (0.063) | (0.073) | (0.061) | (0.034) | (0.074) | (0.053) | (0.058) | (0.069) |
| Meats | 0.012 | 0.023* | 0.066* | −0.748* | 0.136* | 0.045* | 0.042† | 0.031† | 0.005 | −0.132* |
| | (0.025) | (0.006) | (0.014) | (0.034) | (0.021) | (0.009) | (0.023) | (0.020) | (0.020) | (0.021) |
| Poultry | −0.171* | −0.099* | 0.101* | 0.377* | −0.734* | −0.045 | −0.492* | −0.050 | 0.145* | 0.344* |
| | (0.074) | (0.019) | (0.040) | (0.074) | (0.082) | (0.027) | (0.068) | (0.054) | (0.057) | (0.064) |
| Eggs | −0.036 | 0.021 | −0.075 | 0.294* | −0.092 | −0.948* | 0.048 | 0.082† | −0.117* | 0.318* |
| | (0.082) | (0.041) | (0.047) | (0.066) | (0.057) | (0.070) | (0.067) | (0.046) | (0.052) | (0.058) |
| Aquatic p. | −0.036 | −0.050* | −0.108* | −0.057 | −0.452* | 0.006 | −0.710* | 0.059 | −0.095† | 0.388* |
| | (0.081) | (0.019) | (0.043) | (0.073) | (0.060) | (0.028) | (0.099) | (0.057) | (0.058) | (0.071) |
| Vegetables | −0.002 | 0.023* | −0.022 | 0.044 | −0.021 | 0.017† | 0.072* | −0.762* | 0.150* | −0.049 |
| | (0.031) | (0.007) | (0.016) | (0.033) | (0.025) | (0.010) | (0.029) | (0.032) | (0.026) | (0.030) |
| Fruits | 0.008 | 0.032* | −0.038 | −0.008 | 0.099* | −0.039* | −0.024 | 0.191* | −0.886* | 0.076† |
| | (0.047) | (0.011) | (0.025) | (0.048) | (0.037) | (0.016) | (0.042) | (0.036) | (0.048) | (0.041) |
| Dairy p. | −0.120 | 0.009 | −0.103* | −0.547* | 0.349* | 0.141* | 0.498* | −0.161* | 0.072 | −1.093* |
| | (0.092) | (0.022) | (0.048) | (0.082) | (0.067) | (0.030) | (0.086) | (0.073) | (0.069) | (0.120) |
| *Income elasticities* | | | | | | | | | | |
| | 0.366* | 0.410* | 0.311* | 0.547* | 0.654* | 0.530* | 1.109* | 0.578* | 0.619* | 1.004* |
| | (0.002) | (0.004) | (0.004) | (0.001) | (0.005) | (0.003) | (0.007) | (0.002) | (0.003) | (0.008) |

*Note.* Numbers in parentheses are standard errors. "*" and "†" indicate significance at the 5% and 10 levels, respectively.

**TABLE 7** Unconditional price and income elasticities for food commodities consumed at home, rural China, time-series (2000–2012) and cross-provincial (30 provinces)

| Food items | Grains | Vegetable | Oils and fats | Pork | Beef | Poultry | Eggs | Dairy prod. | Aquatic prod. | Fruits |
|---|---|---|---|---|---|---|---|---|---|---|
| *Unconditional Marshallian price elasticities* | | | | | | | | | | |
| Grains | −0.451* | −0.076* | −0.074* | 0.042 | −0.089* | 0.058* | 0.038* | 0.045* | 0.101* | 0.041 |
| | (0.059) | (0.036) | (0.024) | (0.032) | (0.026) | (0.022) | (0.013) | (0.010) | (0.026) | (0.030) |
| Vegetables | −0.254* | −0.388* | −0.055* | −0.126* | −0.015 | −0.053* | −0.031* | −0.037* | −0.050 | −0.043† |
| | (0.052) | (0.054) | (0.024) | (0.039) | (0.028) | (0.022) | (0.011) | (0.010) | (0.026) | (0.030) |
| Oils and fats | −0.451* | −0.163 | −0.226† | −0.101 | 0.021 | 0.027 | 0.115* | 0.090* | 0.112 | −0.168† |
| | (0.134) | (0.103) | (0.115) | (0.104) | (0.083) | (0.074) | (0.046) | (0.029) | (0.091) | (0.094) |
| Pork | −0.038 | −0.081 | −0.033 | −0.481* | −0.045 | −0.012 | 0.026 | −0.012 | −0.024 | 0.003 |
| | (0.062) | (0.054) | (0.035) | (0.060) | (0.036) | (0.028) | (0.016) | (0.013) | (0.032) | (0.038) |
| Beef | −0.953* | −0.266 | −0.005 | −0.402* | −0.378† | 0.228† | −0.006 | 0.028 | −0.147 | 0.134 |
| | (0.248) | (0.215) | (0.140) | (0.190) | (0.217) | (0.124) | (0.064) | (0.056) | (0.130) | (0.166) |
| Poultry | 0.034 | −0.185† | 0.017 | −0.142 | 0.250* | −0.282* | −0.125* | −0.249* | −0.205* | −0.278* |
| | (0.147) | (0.113) | (0.091) | (0.108) | (0.091) | (0.113) | (0.054) | (0.032) | (0.100) | (0.103) |
| Eggs | 0.282† | −0.171† | 0.242* | 0.159 | 0.035 | −0.184† | −1.076* | 0.099* | 0.132 | −0.241* |
| | (0.157) | (0.097) | (0.099) | (0.100) | (0.080) | (0.093) | (0.126) | (0.028) | (0.119) | (0.100) |
| Dairy p. | 0.510* | −0.309* | 0.265* | −0.114 | 0.104 | −0.551* | 0.139* | −0.828* | 0.135 | −0.040 |
| | (0.168) | (0.146) | (0.085) | (0.127) | (0.097) | (0.077) | (0.039) | (0.053) | (0.096) | (0.102) |
| Aquatic p. | 0.272 | −0.026 | 0.160 | −0.157 | 0.012 | −0.170 | 0.087 | 0.060 | −0.844* | −0.209 |
| | (0.222) | (0.150) | (0.135) | (0.140) | (0.111) | (0.116) | (0.084) | (0.045) | (0.206) | (0.145) |
| Fruits | 0.042 | −0.078 | −0.133† | −0.012 | 0.096 | −0.161* | −0.092* | −0.014 | −0.117 | −0.347* |
| | (0.129) | (0.102) | (0.073) | (0.091) | (0.076) | (0.066) | (0.036) | (0.026) | (0.076) | (0.117) |
| *Income elasticities* | | | | | | | | | | |
| | 0.389* | 1.123* | 0.794* | 0.745* | 1.885* | 1.243* | 0.771* | 0.734* | 0.868* | 0.869* |
| | (0.003) | (0.014) | (0.017) | (0.009) | (0.085) | (0.027) | (0.016) | (0.041) | (0.034) | (0.019) |

Notes: Numbers in parentheses are standard errors. "*" and "†" indicate significance at the 5% and 10 levels, respectively.

results of this study, however, actually reflect farmer's situation of budget constraints when making purchasing decisions.[11] Finally, the elasticity estimates in the first stage from this study suggest that food expenditures in China are expected to continue growing while FAFH expenditures in China are expected to rise at a higher rate as compared to FAH spending as per capita incomes grow further.

For urban residents (Table 6), the income elasticities of meats, poultry, eggs, aquatic products, dairy products, fruits, and vegetables range from 0.53 to 1.109 and are considerably higher than those of grains, oils, and beans that range from 0.311 to 0.41. In particular, the income elasticities of aquatic products and dairy products are the highest. For rural residents (Table 7), the income elasticities of beef and mutton, poultry meat, and vegetables are higher than one, and the elasticities for other seven commodities range from 0.389 to 0.869. While the elasticities from this study are not exactly the same as those from previous studies, all the elasticity estimates for both urban and rural residents from this study fall within the range of elasticities of previous studies surveyed by Abler (2010) and Chen, Abler, Zhou, Yu, and Thompson (2015). As noted by Abler (2010), differences of elasticities from different studies might be attributed to the time period for the data analyzed in a study, as well as whether a study uses a single-stage demand system model or a two- or three-stage demand system model.

It is noted that the income elasticity of vegetables for rural residents from this study is relatively larger than other foods in the system, which is similar to that from Gao et al. (1996) and Huang and Rozelle (1998). The larger income elasticity of vegetables relative to other foods implies that the budget share of vegetables consumed would rise at a much larger rate as compared to those of other foods if holding prices constant, which is in contrast with the declining trend of budget shares of vegetables observed over past two decades. Data from *China Yearbook of Rural Household Survey* show that the national average of quantity consumed of vegetables has decreased since 1990 while the cross-sectional data for each year indicate that the quantity consumed of vegetables by income category has increased with income levels. It appears that the elasticity of vegetables from this study might reflect cross-sectional trend. Indeed, further research on this subject is still needed.

A comparison of the income elasticities of demand for at-home foods between urban and rural residents can shed light on food demand patterns observed and in the future in China. While the elasticities of dairy products and aquatic products are lower for rural residents than for urban residents, the elasticities for other seven commodities, including grains, vegetables, oils and fats, meats including pork, beef, and mutton, poultry, eggs, and fruits, are considerably higher for rural residents than for urban residents. The results of this study suggest that, if prices and noneconomic variables are held constant, per capita consumption of major food commodities is expected to increase at a higher rate for rural residents than for urban residents as per capita incomes further rise. It is hence concluded that urbanization is expected to be the main force driving future changes in the structure of food demand for the population as a whole in China.

The age composition variables adopted in this study, that is the proportion of seniors 65 and over and of children aged 0–14 to total population, are mainly used to examine the impact of population aging on food demand. Thus, the role these demographic variables have played on food demand can be easily seen through combining the elasticity estimates with variations observed of the variables during 2000–2012. Over the studied period, for both urban and rural residents, the proportion of seniors aged 65 years and over rose while the proportion of children aged 0–14 fell. For urban residents (Table 4), changes in age composition related to population aging increased the demand for aquatic products, vegetables, and fruits; while decreasing the demand for grains, beans, oils and fats, and meats. For rural residents (Table 5), changes in age composition raised the demand for pork, beef and mutton, eggs, and dairy products; whereas lowering the demand for grains, oils and fats, poultry meat, and fruits. Thus, the results of this study suggest that, holding other variables constant, changes in age composition are expected to

[11]Except for Ma, Huang, and Hu (2001) that provides the elasticity of demand for FAFH for rural residents, there are no studies found in literature focused on the demand for FAFH for China's rural residents. The income elasticity for FAFH from Ma et al. (2001) is 1.72, which is much larger than that from our study. While the data used by Ma et al. (2001) were from a three-day consumption survey of 235 households in 1998, FAFH spending from this survey was much larger than the national average in 2000, suggesting that our study is not comparable with Ma et. (2001). Further studies on the demand for FAFH for rural residents are needed in that farmers' FAFH spending has grown rapidly since 2000.

**TABLE 8** Variables and their changing rates used for predicting changes in the food demand in 2030, China

| Variables | 2012 Urban | 2012 Rural | 2030 Urban | 2030 Rural |
|---|---|---|---|---|
| High income | 15,845 | 6,332 | 28,567 | 13,720 |
| Medium income | 15,845 | 6,332 | 26,291 | 12,292 |
| Low income | 15,845 | 6,332 | 24,168 | 11,007 |
| Proportion of children aged 0–14 | 13.14% | 18.08% | 7.33% | 10.27% |
| Proportion of seniors aged 65 and above | 8.27% | 10.02% | 9.87% | 16.13% |
| Shares of urban and rural residents | 52.57% | 47.43% | 69.3% | 30.7% |

*Note*. Total expenditures proxy incomes, which are estimated using expenditure elasticities with respect to per capita GDP for the year 2030. The expenditure elasticities with respect to GDP are 0.4797 and 0.6116 for urban and rural residents, respectively, using pooled provincial and time-series data from 2000 to 2012. Unit on incomes is Chinese Yuan.

drive down the demand for grains, oils and fats, and poultry meat while driving up the demand for vegetables, eggs, dairy products, and aquatic products for the population as a whole.

## 6 | PREDICTING THE CHANGES IN FOOD DEMAND IN THE FUTURE

While the demand elasticity estimates, as documented above, have shed light on the patterns of food demand changes in China, a simple prediction with these elasticities might provide even a clearer picture on the changes in food demand in the future. In this light, the objective of this section is to investigate the impact of income growth, urbanization, and population aging on the structure of food demand for the year 2030, using the estimated demand elasticities with respect to income and demographic variables.[12] More specifically, the predictions in this section will focus on changes in the budget shares of urban and rural residents as well as of Chinese population as a whole, with respect to the 2012 price levels. Four scenarios are considered for this prediction. The 1st through the 3rd scenarios involve increasing total expenditures, population aging rates, and urbanization rates, one-at-a-time, while holding all other variables constant. The 4th scenario shows the combined effects of the simultaneous changes in the 1st through the 3rd scenarios on the structure of food demand, while keeping all other variables constant.

Assuming 7.5%, 6.5%, and 5.5%, for high, medium, and low growth rates of per capita gross domestic products (GDP) in China, respectively, during 2010–2020 and 6.5%, 5.5% and 4.5% from 2020 to 2030, respectively; total expenditures for urban and rural residents in 2030 are estimated using the corresponding elasticities of total expenditures with respect to GDP. From 2000–2012, for urban and rural residents, respectively, the proportion of population 65 years and over rose at average annual rates of 0.99% and 2.69%, while the proportion of the children aged 0–14 declined at average annual rates of 3.19% and 3.07%. Assuming that the rates of changes in age composition are held constant, the values of these two variables in 2030 are estimated accordingly. The urbanization rate in 2030 is set at 0.693, which is from a forecast provided by NBSC; while the rate in 2012 is set at 0.5257, which is from China Statistical Yearbook. The proportions of urban and rural residents are calculated from these figures for 2012 and 2030, respectively. The variables and their changing rates described above are presented in Table 8.

### 6.1 | Impacts of income growth

Consistent with Engel's law, the proportions of food expenditures to total expenditures for both urban and rural residents are expected to fall as per capita incomes grow. Estimates show that, within the food-expenditure

[12]A number of demand elasticities with respect to demographic variables are not significant at 10% level, and thus all elasticities with significant level (p value) being higher than 16% are set to zero.

**TABLE 9** Predicted impacts of income growth and of population aging, respectively, on the structure of food demand for urban and rural residents, respectively, Step II, China in 2030

| | Urban residents | | | | | Rural residents | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Income impact | | | | | Income impact | | |
| | Actual in 2012 | Demographic impact[a] | High | Medium | Low | Actual in 2012 | Demographic impact | High | Medium | Low |
| *Total expenditure* (100%) | | | | | | | | | | |
| Food | 30.4 | 30.2 (−0.02) | 26.8 (−0.70) | 27.1 (−0.62) | 27.6 (−0.53) | 34.4 | 35.5 (0.17) | 32.0 (−0.42) | 32.2 (−0.37) | 32.5 (−0.33) |
| *Food expenditure* (100%) | | | | | | | | | | |
| FAFH | 26.5 | 27.5 (0.22) | 30.5 (0.80) | 30.0 (0.71) | 29.5 (0.61) | 16.3 | 16.9 (0.21) | 16.9 (0.19) | 16.8 (0.17) | 16.7 (0.15) |
| FAH | 73.5 | 72.5 (−0.08) | 69.5 (−0.32) | 70.0 (−0.28) | 70.5 (−0.24) | 83.7 | 83.1 (−0.04) | 83.1 (−0.04) | 83.2 (−0.03) | 83.3 (−0.03) |
| *FAH expenditure* (100%) | | | | | | | | | | |
| Grains | 12.8 | 12.9 (0.05) | 11.0 (−0.82) | 11.2 (−0.71) | 0.115 (−0.60) | 23.2 | 21.8 (−0.34) | 16.9 (−1.75) | 17.6 (−1.53) | 18.3 (−1.30) |
| Vegetables | 16.5 | 15.0 (−0.51) | 16.1 (−0.14) | 16.1 (−0.12) | 0.162 (−0.10) | 22.1 | 21.5 (−0.13) | 25.5 (0.81) | 25.1 (0.73) | 24.7 (0.64) |
| Oils and fats | 4.5 | 4.3 (−0.17) | 3.7 (−1.01) | 3.8 (−0.87) | 0.039 (−0.73) | 6.4 | 6.3 (−0.03) | 6.2 (−0.20) | 6.2 (−0.18) | 6.2 (−0.15) |
| Meats | 25.0 | 25.0 (0.00) | 24.0 (−0.23) | 24.1 (−0.20) | 0.243 (−0.17) | 24.7 | 26.3 (0.34) | 27.0 (0.49) | 26.7 (0.44) | 26.5 (0.39) |
| Poultry | 7.1 | 7.2 (0.10) | 7.2 (0.09) | 7.2 (0.08) | 0.072 (0.07) | 4.3 | 3.9 (−0.46) | 5.2 (1.14) | 5.1 (1.03) | 5.0 (0.90) |
| Eggs | 3.1 | 3.1 (0.05) | 2.9 (−0.29) | 2.9 (−0.25) | 0.030 (−0.21) | 3.0 | 3.9 (1.55) | 2.8 (−0.28) | 2.8 (−0.25) | 2.9 (−0.21) |
| Dairy products | 7.2 | 7.3 (0.10) | 8.6 (1.03) | 8.4 (0.91) | 0.082 (0.78) | 2.4 | 3.0 (1.18) | 2.2 (−0.40) | 2.2 (−0.36) | 2.3 (−0.31) |

(Continues)

**TABLE 9** (Continued)

| | Urban residents | | | | | Rural residents | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Income impact | | | | | Income impact | | |
| | Actual in 2012 | Demographic impact[a] | High | Medium | Low | Actual in 2012 | Demographic impact | High | Medium | Low |
| Aquatic products | 9.9 | 10.2<br>(0.13) | 12.5<br>(1.29) | 12.2<br>(1.14) | 0.118<br>(0.98) | 5.0 | 4.9<br>(−0.13) | 5.1<br>(0.05) | 5.1<br>(0.04) | 5.1<br>(0.04) |
| Fruits | 14.0 | 14.9<br>(0.36) | 13.9<br>(−0.01) | 13.9<br>(−0.01) | 0.139<br>(−0.01) | 9.0 | 8.3<br>(−0.45) | 9.1<br>(0.05) | 9.1<br>(0.04) | 9.1<br>(0.04) |

*Note.* Figures in the parentheses are annualized growth rates in percentage during 2012–2030. FAH: food at home; FAFH: food away from home.

[a]Demand elasticities with respect of demographic variables with standard errors higher than 16% levels are set to be zero.

category, the shares of FAH spending would fall while the shares of FAFH spending would rise for both urban and rural residents (Table 9). For urban residents, per capita income growth is expected to decrease at-home food budget shares of grains, vegetables, oils and fats, meats, eggs, and fruits, while increasing the budget shares of poultry meat, dairy products, and aquatic products. For rural residents, with growth of per capita incomes continuing into the future, the at-home food budget shares of grains, oils and fats, eggs, and dairy products are expected to rise, whereas the budget shares of other foods at home are expected to fall.

## 6.2 | Impacts of population aging

Changes in China's population's age composition are expected to slightly decrease food's expenditure shares of total expenditures for urban residents, while increasing food's expenditure shares for rural residents. Moreover, the predicted changes in age composition would increase the shares of FAFH spending while decreasing the shares of FAH expenditures for both urban and rural residents (Table 9). For urban residents, the changes in age composition are expected to decrease at-home food budget shares of vegetables and oils and fats, whereas increasing the budget shares of other seven commodities. For rural residents, the changes in age composition are expected to increase at-home budget shares of meats, eggs, and dairy products, while decreasing the budget shares of other six commodities.

## 6.3 | Impacts of urbanization

**TABLE 10** Predicted impacts of urbanization and of combined income growth, population aging, and urbanization, respectively, on the structure of food demand for the population as a whole, Step II, China in 2030

| | | | Combined impacts | | |
|---|---|---|---|---|---|
| | Actual in 2012 | Urbanization impact | High | Medium | Low |
| *Total expenditure* (100%) | | | | | |
| Food | 31.4 | 31.0<br>(−0.08) | 27.7<br>(−0.70) | 28.0<br>(−0.63) | 28.4<br>(−0.56) |
| *Food expenditure* (100%) | | | | | |
| FAFH | 23.5 | 24.8<br>(0.29) | 28.3<br>(1.04) | 28.0<br>(0.98) | 27.7<br>(0.92) |
| FAH | 76.5 | 75.2<br>(−0.09) | 71.7<br>(−0.36) | 72.0<br>(−0.34) | 72.3<br>(−0.31) |
| *FAH expenditure* (100%) | | | | | |
| Grains | 16.1 | 14.7<br>(−0.49) | 12.3<br>(−1.48) | 12.6<br>(−1.36) | 12.9<br>(−1.23) |
| Vegetables | 18.2 | 17.5<br>(−0.23) | 17.5<br>(−0.23) | 17.3<br>(−0.28) | 17.2<br>(−0.34) |
| Oils and fats | 5.1 | 4.8<br>(−0.28) | 4.2<br>(−1.02) | 4.3<br>(−0.95) | 4.3<br>(−0.87) |
| Meats | 24.9 | 25.0<br>(0.01) | 24.9<br>(−0.01) | 24.9<br>(0.00) | 25.0<br>(0.01) |
| Poultry | 6.2 | 6.6<br>(0.33) | 6.8<br>(0.49) | 6.8<br>(0.47) | 6.7<br>(0.46) |
| Eggs | 3.0 | 3.1<br>(0.03) | 3.0<br>(−0.03) | 3.1<br>(0.02) | 3.1<br>(0.08) |
| Dairy products | 5.6 | 6.3<br>(0.59) | 7.2<br>(1.40) | 7.2<br>(1.33) | 7.1<br>(1.25) |
| Aquatic products | 8.4 | 9.0<br>(0.41) | 10.9<br>(1.46) | 10.7<br>(1.36) | 10.5<br>(1.24) |
| Fruits | 12.4 | 13.0<br>(0.28) | 13.2<br>(0.34) | 13.2<br>(0.36) | 13.3<br>(0.39) |

*Note.* Figures in the parentheses are annualized growth rates in percentage during 2012–2030.

Assuming that rural people who had migrated from rural to urban areas have the same food preferences and incomes as those of urban people, for Chinese population as a whole, the predicted changes in urbanization rates from 0.5257 in 2012 to 0.693 in 2030 would decrease the proportions of food expenditures to total expenditures and the shares of FAFH spending in the food expenditure while increasing the shares of FAH spending (Table 10), which is the same as the income impact. This is expected because the shares of food expenditure in the total expenditures and of FAH spending in the food expenditures are lower while the shares of FAFH spending are higher for urban residents as compared to those for rural residents. For at-home food budget shares for whole population in China, the predicted growth in urbanization rates would decrease the budget shares of grains, vegetables, and oils and fats while increasing the budget shares of foods with animal origin and fruits (Table 10).

### 6.4 | The combined impacts

What are the combined impacts of changes in income, population aging, and urbanization on food demand in China? As shown in the last three columns of Table 10, as per capita incomes rise while urbanization and population aging continue their upward trends, both the proportions of food expenditure to total expenditure and the shares of FAH spending in the food expenditures are expected to decline, while the shares of FAFH spending are expected to rise. In comparison with the annualized growth rates in the shares among the scenarios for either urban or rural residents (Table 9), the changing rates in the shares from the combined effects for Chinese population as a whole are much larger than those driven by either of three scenarios alone.

For at-home foods, the budget shares of grains, vegetables, and oils and fats are expected to fall, the budget shares of poultry meat, dairy products, aquatic products, and fruits are expected to rise, and the budget shares of meats and eggs are expected to remain almost unchanged (Table 10). In summary, the budget shares of grains, vegetables, and oils and fats are expected to fall, whereas the budget shares of foods with animal origin and fruits are expected to rise. It is noted that the budget shares of beef and mutton are expected to rise at a much higher rate than that of pork for rural residents, it is hence conjectured that the budget shares of pork would fall slightly as compared to those for other animal food products for the population as a whole.

## 7 | CONCLUDING REMARKS

This study examines the impact of income growth, urbanization, and population aging on the structure of food demand for urban and rural residents as well as for Chinese population as a whole, using a two-stage AIDS–QUAIDS model and pooled provincial and time-series data from 2000 to 2012 for both urban and rural residents in China. Results of this study show that, as per capita incomes grow while both urbanization and population aging continue their upward trends from 2012 to 2030, the proportions of food expenditures to total expenditures would fall, the shares of FAFH spending to food expenditures are expected to be on the rise while the shares of FAH spending would decrease, and the at-home food budget shares of grains, vegetables, and oils and fats are expected to decline while the at-home food budget shares of foods with animal origins and fruits would rise. Since FAFH is mainly composed of animal food products, oils and fats, and vegetables, it is concluded that the budget shares of grains would fall while the budget shares of foods with animal origin and fruits are expected to rise, with a much larger rate in the total food expenditures than in the at-home food expenditures, and that the budget shares of vegetables and oils and fats in food expenditures are expected to change slightly.

The findings of this study have an important implication for China and world agriculture. Dietary patterns in China are expected to continue their trend toward higher consumption of foods with animal origin. More specifically, it is expected that in the future the proportion of foods with animal origin in total food consumption continues its upward trend, leading to an increase in the demand for feed grains in China. Therefore, food security in China has actually been feed grain security. During 2004–2016, grain output in China has increased at an average annual growth rate of 2.3%, which is significantly higher than the population growth rate of 0.5% per year. During the same period, China's net imports of grains have increased. Since the mid-1990s, especially after becoming a member of WTO in 2001, China's imports of soybeans have soared, making China shifting its trade status from being self-sufficient to becoming the world's largest soybean importer. For corn, while China used to be a net exporter to the world market, it has become a net importer since 2009. China has accumulated a large amount of corn stock in the recent years, which results mainly from price support policy and does not suggest that China's food security is guaranteed in consideration of China's large amount of population with limited land and other resources. From the results of this study, it can be concluded that the heavy reliance of China on the world markets to meet its demand for feed grains will continue in the future.

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**How to cite this article:** Zheng Z, Henneberry SR, Zhao Y, Gao Y. Predicting the changes in the structure of food demand in China. *Agribusiness*. 2019;35:301–328. https://doi.org/10.1002/agr.21592

## APPENDIX A

**TABLE A1** Summary of estimated coefficients and equation $R^2$s for urban residents, Step I, Stage II, food-at-home, time-series (2000–2012) and cross-provincial (31 provinces)

| | Coefficients of | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Explanatory variables | Grains | Fats and Oils | Meats | Poultry | Eggs | Aquatic products | Vegetables. | Fruits | Dairy products |
| Cons | 0.3643** | 0.3440** | 0.0512 | −0.1065 | −0.1189** | 0.4970** | 0.4923** | 0.4494** | −1.0150** |
| u014 | −0.0002 | 0.0003* | 0.0006 | 0.0003 | 0.0001 | 0.0006 | −0.0011** | −0.0012** | 0.0004 |
| u65 | −0.0009** | 0.0002 | −0.0007* | 0.0003 | −0.0002 | 0.0008** | 0.0005 | 0.0000 | 0.0000 |
| ln(p_Grains) | 0.0626** | | | | | | | | |
| ln(p_Fats and oils) | −0.0111 | −0.0119 | | | | | | | |
| ln(p_Meats) | −0.0165 | 0.0391** | 0.0028 | | | | | | |
| ln(p_Poultry) | −0.0157 | 0.0307** | 0.0043 | 0.0038 | | | | | |
| ln(p_Eggs) | −0.0042 | 0.0147* | −0.0095 | −0.0162** | −0.0080 | | | | |
| ln(p_Aquatic products) | 0.0090 | −0.0840** | 0.0729** | 0.0064 | 0.0408** | −0.1622** | | | |
| ln(p_Vegetables) | −0.0136 | −0.0465** | 0.0208 | 0.0153 | 0.0188** | −0.0731** | −0.0127 | | |
| ln(p_Fruits) | −0.0074 | −0.0495** | 0.0226 | 0.0341** | 0.0142 | −0.0962** | −0.0274* | −0.0391 | |
| ln(p_Dairy products) | 0.0054 | 0.1241** | −0.1396** | −0.0548 | −0.0512** | 0.2905** | 0.1167** | 0.1462** | −0.4400** |
| ln(p_Beans) | −0.0086** | −0.0057 | 0.0031 | −0.0080** | 0.0006 | −0.0041 | 0.0016 | 0.0025 | 0.0028 |
| ln(x) | −0.0042 | −0.1061** | 0.0869** | 0.0654** | 0.0517** | −0.2213** | −0.1065** | −0.1169** | 0.3523** |
| $\ln(x)^2$ | −0.0049 | 0.0076** | −0.0104** | −0.0056* | −0.0053** | 0.0273** | 0.0091** | 0.0110** | −0.0283** |
| Adj. $R^2$ | 0.909 | 0.810 | 0.911 | 0.944 | 0.933 | 0.969 | 0.804 | 0.852 | 0.819 |

*Note*. Single and double asterisks (* and **) denote statistical significance at the 10% and 5% levels, respectively. u014 and u65 stand for the variables on the proportion of children aged 0–14 and of persons 65 years and over in urban China, respectively.

**TABLE A2** Summary of estimated coefficients and equation $R^2$s for rural residents, Step I, Stage II, food-at-home, time-series (2000–2012) and cross-provincial (30 provinces)

| | Coefficients of | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Explanatory Variables | Grains | Vegetables | Oils and fats | Pork | Beef and mutton | Poultry | Eggs | Dairy products | Aquatic products |
| Cons | 0.1780 | −0.4712** | −0.4541** | 0.6168** | 0.1149 | −0.6401** | 0.3350** | −0.1355** | 1.2881** |
| r014 | 0.2182** | 0.0348 | 0.0879** | −0.1518** | −0.1492** | 0.0390 | −0.0487** | −0.0992** | −0.0178 |
| r65 | 0.0190 | −0.0993 | 0.0779 | −0.1306 | −0.0696 | 0.0541 | 0.0787** | 0.0307 | 0.0571 |
| Market | −0.3253** | 0.0455 | 0.0605** | −0.1402** | 0.0378 | 0.0234* | 0.0347** | 0.0391** | 0.0941** |
| ln(p_Grains) | −0.0357 | | | | | | | | |
| ln(p_Vegetables) | −0.1108** | 0.0693 | | | | | | | |
| ln(p_Oils and fats) | −0.0852** | −0.0503** | 0.0183** | | | | | | |
| ln(p_Pork) | 0.0272 | 0.0131 | 0.0171 | 0.0555** | | | | | |
| ln(p_Beef and mutton) | 0.0158 | 0.0091 | 0.0163 | −0.0231** | 0.0088 | | | | |
| ln(p_Poultry) | −0.0693** | −0.0667** | −0.0378** | 0.0330 | 0.0317* | −0.0225 | | | |
| ln(p_Eggs) | 0.0511** | 0.0256 | 0.0288 | −0.0187 | −0.0123 | 0.0273 | −0.0215 | | |
| ln(p_Dairy products) | −0.0142 | −0.0226** | −0.0059** | 0.0071 | 0.0084* | −0.0272** | 0.0118** | −0.0012 | |
| ln(p_Aquatic products) | 0.1950** | 0.1259** | 0.0972** | −0.0958** | −0.0535 | 0.1261** | −0.0742** | 0.0397** | −0.3082** |
| ln(p_Fruits) | 0.0259 | 0.0075 | 0.0015 | −0.0153 | −0.0012 | 0.0054 | −0.0180 | 0.0039 | −0.0522 |
| ln(x) | 0.2265** | 0.1577** | 0.1114** | −0.1078** | −0.0651 | 0.1625** | −0.0946** | 0.0457** | −0.3836** |
| $\ln(x)^2$ | −0.0239** | −0.0044 | −0.0071** | 0.0060* | 0.0071** | −0.0086** | 0.0059** | −0.0030** | 0.0244** |
| Adj. $R^2$ | 0.928 | 0.850 | 0.714 | 0.912 | 0.939 | 0.936 | 0.931 | 0.907 | 0.947 |

*Note*. Single and double asterisks (*,**) denote statistical significance at the 10% and 5% levels, respectively. r014 and r65 stand for the variables on the proportion of children aged 0–14 and of persons 65 years and over in rural China, respectively. Market represents market development index.

**TABLE A3** Conditional compensated price elasticities for food commodities, urban China, time-series (2000–2012) and cross-provincial (31 provinces)

| | Grains | Beans | Oils and fats | Meats | Poultry | Eggs | Aquatic prod. | Vegetables | Fruits | Dairy prod. |
|---|---|---|---|---|---|---|---|---|---|---|
| Grains | −0.329* | −0.035* | 0.015 | 0.165 | −0.058* | 0.006 | 0.060 | 0.081* | 0.080* | 0.014 |
| | (0.062) | (0.015) | (0.027) | (0.036) | (0.038) | (0.021) | (0.047) | (0.030) | (0.036) | (0.045) |
| Beans | −0.220* | −0.181* | −0.182* | 0.416* | −0.350* | 0.058 | −0.165† | 0.266* | 0.269* | 0.090 |
| | (0.107) | (0.091) | (0.066) | (0.073) | (0.075) | (0.075) | (0.085) | (0.052) | (0.066) | (0.080) |
| Oils and fats | 0.050 | −0.076* | −0.381* | 0.456* | 0.195* | −0.039 | −0.122† | 0.014 | −0.017 | −0.081 |
| | (0.074) | (0.026) | (0.063) | (0.062) | (0.061) | (0.034) | (0.072) | (0.048) | (0.057) | (0.068) |
| Meats | 0.085* | 0.034* | 0.092* | −0.628* | 0.177* | 0.064* | 0.088* | 0.113* | 0.068* | −0.092* |
| | (0.022) | (0.006) | (0.014) | (0.027) | (0.020) | (0.009) | (0.022) | (0.016) | (0.019) | (0.020) |
| Poultry | −0.084 | −0.086* | 0.133* | 0.520* | −0.684* | −0.022 | −0.437* | 0.049 | 0.220* | 0.391* |
| | (0.067) | (0.019) | (0.039) | (0.059) | (0.082) | (0.026) | (0.067) | (0.047) | (0.055) | (0.064) |
| Eggs | 0.034 | 0.031 | −0.050 | 0.411* | −0.051 | −0.929* | 0.093 | 0.161* | −0.056 | 0.356* |
| | (0.078) | (0.041) | (0.047) | (0.058) | (0.057) | (0.069) | (0.066) | (0.041) | (0.052) | (0.060) |
| Aquatic p. | 0.111 | −0.028 | −0.055 | 0.186* | −0.369* | 0.045† | −0.616* | 0.226* | 0.033 | 0.468* |
| | (0.074) | (0.019) | (0.041) | (0.056) | (0.060) | (0.027) | (0.097) | (0.049) | (0.055) | (0.071) |
| Vegetables | 0.075* | 0.034* | 0.006 | 0.171* | 0.023 | 0.038 | 0.121* | −0.675* | 0.216* | −0.007 |
| | (0.027) | (0.007) | (0.015) | (0.024) | (0.024) | (0.010) | (0.028) | (0.029) | (0.024) | (0.030) |
| Fruits | 0.090* | 0.045* | −0.008 | 0.128* | 0.146* | −0.017 | 0.028 | 0.284* | −0.816* | 0.120* |
| | (0.042) | (0.011) | (0.024) | (0.037) | (0.036) | (0.016) | (0.041) | (0.031) | (0.047) | (0.041) |
| Dairy prod. | 0.013 | 0.028 | −0.054 | −0.326* | 0.425* | 0.176* | 0.582* | −0.011 | 0.187* | −1.021* |
| | (0.084) | (0.021) | (0.046) | (0.061) | (0.067) | (0.029) | (0.084) | (0.063) | (0.065) | (0.122) |

*Note*. Numbers in parentheses are standard errors. “*” and “†” indicate significance at the 5% and 10 levels, respectively.

**TABLE A4** Conditional compensated price elasticities for food commodities, rural China, time-series (2000–2012) and cross-provincial (30 provinces)

| | Grains | Vegetables | Oils and fats | Pork | Beef | Poultry | Eggs | Dairy Prod. | Aquatic prod. | Fruits |
|---|---|---|---|---|---|---|---|---|---|---|
| Grains | −0.342* | 0.006 | −0.053* | 0.106* | −0.076* | 0.074* | 0.049* | 0.052* | 0.115* | 0.069* |
| | (0.054) | (0.030) | (0.024) | (0.030) | (0.026) | (0.021) | (0.013) | (0.009) | (0.026) | (0.030) |
| Vegetables | 0.059 | −0.152* | 0.007 | 0.056† | 0.023 | −0.003 | −0.002 | −0.016 | −0.008 | 0.037 |
| | (0.040) | (0.044) | (0.023) | (0.032) | (0.028) | (0.020) | (0.010) | (0.010) | (0.025) | (0.029) |
| Oils and fats | −0.229† | 0.004 | −0.181 | 0.028 | 0.048 | 0.062 | 0.135* | 0.104* | 0.141 | −0.112 |
| | (0.122) | (0.089) | (0.115) | (0.099) | (0.084) | (0.073) | (0.046) | (0.028) | (0.091) | (0.092) |
| Pork | 0.169* | 0.075† | 0.008 | −0.360* | −0.020 | 0.021 | 0.046* | 0.001 | 0.003 | 0.056 |
| | (0.052) | (0.042) | (0.034) | (0.056) | (0.036) | (0.027) | (0.015) | (0.013) | (0.031) | (0.037) |
| Beef | −0.427† | 0.130 | 0.099 | −0.097 | −0.314 | 0.311* | 0.044 | 0.063 | −0.076 | 0.268† |
| | (0.219) | (0.181) | (0.137) | (0.173) | (0.218) | (0.120) | (0.062) | (0.054) | (0.126) | (0.161) |
| Poultry | 0.380* | 0.076 | 0.086 | 0.060 | 0.291* | −0.227* | −0.093† | −0.226* | −0.158 | −0.190† |
| | (0.135) | (0.098) | (0.091) | (0.100) | (0.091) | (0.112) | (0.054) | (0.031) | (0.099) | (0.101) |
| Eggs | 0.497* | −0.009 | 0.284* | 0.284* | 0.061 | −0.151† | −1.056* | 0.114* | 0.162 | −0.186† |
| | (0.141) | (0.084) | (0.098) | (0.094) | (0.080) | (0.091) | (0.127) | (0.027) | (0.119) | (0.098) |
| Dairy prod. | 0.715* | −0.155 | 0.306* | 0.005 | 0.129 | −0.519* | 0.159* | −0.814* | 0.162† | 0.012 |
| | (0.144) | (0.115) | (0.083) | (0.111) | (0.096) | (0.073) | (0.038) | (0.052) | (0.092) | (0.097) |
| Aquatic p. | 0.514* | 0.156 | 0.207 | −0.015 | 0.042 | −0.131 | 0.110 | 0.076† | −0.812* | −0.147 |
| | (0.195) | (0.133) | (0.135) | (0.127) | (0.112) | (0.115) | (0.084) | (0.045) | (0.205) | (0.143) |
| Fruits | 0.285* | 0.104 | −0.085 | 0.129 | 0.126† | −0.122† | −0.069† | 0.003 | −0.085 | −0.285* |
| | (0.117) | (0.087) | (0.072) | (0.083) | (0.076) | (0.063) | (0.036) | (0.026) | (0.075) | (0.115) |

*Note.* Numbers in parentheses are standard errors. "*" and "†" indicate significance at the 5% and 10 levels, respectively.