Demographics, Societal Aging, and Meat Consumption in China

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Abstract:

Drawn on the data collected by surveying 1,340 urban households from 6 cities in China, this paper estimates the impacts of demographic structure and population aging on household meat consumption, by jointly considering meat consumed at-home and away-from-home. Based on the trajectories of population, a simple simulation on meat demand trend in China is conducted subsequently. The results suggest: 1) Meat consumed away-from-home averagely accounts for near 30% of household total meat consumption in terms of quantity, so that its omission likely leads to a significant underestimate of total meat consumption and misunderstanding the driving forces; 2) Population aging significantly and negatively affects per capita meat consumption, suggesting that the expected meat demand in China without considering population aging will be overestimated. The findings from this study have important implications for better understanding the relative issues on China's meat consumption under the situation of population aging.

Key words: *Food away from home; Meat consumption; Aging; China*

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1. Introduction

China, the world's most populous country, is experiencing dramatic changes in its society due to rapid economic growth and the significant aging of its population. The rapid and sustained economic growth has transformed China from a centrally planned low-income country to a middle-income market economy in just three decades (Sutherland and Yao, 2011). At the same time, the population age structure in China is also changing with fewer births due to the "one couple one child" policy and longer life expectancy since 1980s (Chen and Liu, 2009). Following the dramatic fertility and mortality declines, China at the turn of the twenty-first century is joining the ranks of aging societies elsewhere in the world and at a rapid pace (Wang and Andrew, 2007; Flaherty et al., 2007; Banister et al., 2010; Peng, 2011). According to China's national population census in 2010, 13.3% of the populations is 60 years old and above. The United Nations (2013) reports the proportion of China's population aged 60 years old and above is 13.8% in 2013, and it expects China to experience very fast ageing over the coming decades. The percentage aged 60 years old and above in China is predicted to grow to 20% by 2025 (Xie, 2004), and to 30% by 2050 (Du et al., 2005).

While numerous studies from various perspectives address population aging and economic growth in China (Cai and Wang, 2006; Wang and Andrew, 2007; Chen and Liu, 2009; Banister et al., 2010; Li and Shen, 2013), there is a paucity of studies that addresses the impacts of the aging population on food consumption. According to Huang (1999), an increasing proportion of aged population will likely decrease the per capita consumptions of almost all foods while Zhou et al. (2012) project it may reduce meat consumption, but increase consumption of other foods. They also state that such possible impacts are yet to emerge or to be seen. In terms of caloric intake, Zhong and Xiang (2012) find significant evidence that demographic structure affects grain demand in China and thus caloric intake. Additionally, Xiang (2012) estimates income and price elasticities of calorie consumption in China under the situations of including and excluding demographic structure, and he finds that, if the impacts of demographic structure on food consumption are neglected, food demand and food security caused by economic factors may be overstated in China. However, due to the nature of their demographic structure variables, these latter two studies do not clearly measure the effect of age. If China's rapid process of population aging has significant effects on its food demand, it is imperative to measure and understand these effects as, given it huge population base, any changes in China's food consumption can cause marked effects on domestic food supply and even on world agricultural product markets (Huang et al., 1999; Seale et al., 2012).

In fact, food consumption in China has gradually transformed from a staple food dominated dietary structure to one including more animal products (Yen et al., 2004; Ma et al., 2004; Yu and Abler, 2009). These dietary transformations are mainly driven by income growth, urbanization, and the establishment of a market economy (Huang and Scott, 1998; Gould and Hector, 2006). Over the last three decades, per capita grain consumption in urban (rural) China has declined from 145.4 kg (256.1 kg) in 1981 to 78.8 kg (164.3 kg) in 2012. During the same period, per capita meat consumption has increased 74% in urban China and 134% in rural China (NBSC, 2013). As meat production normally is a grain intensive activity, increased demand for meat not only puts direct pressure on China's meat production and supply, but it also indirectly puts pressure on China's grain production and supply, both of which increase the risks of food security in China (Seale et al., 2012; Huang et al., 2012). Accordingly, an assessment of future food security in China necessitates accurate projections of China's meat demand. To do so requires going beyond the effects of changing income and prices, and it is important to include the effects from a changing demographic structure, particularly in terms of the demand for meats by different age groups. For example, Wang et al. (2005) states that the demand for animal products by aged, middle-aged, and younger populations is quite different. Therefore, a relatively higher proportion of the aged population is likely to have an impact on the kinds and amount of animal products demanded in China. Unfortunately, there are currently no studies that adequately measure the impacts of demographic structure and aging on meat consumption in China.

International evidence shows that population aging usually has a negative effect on per capita meat consumption in many developed countries. Gossard (2003) explores the influences of social structural on U.S. meat consumption, using data from the 1996 Continuing Survey of Food Intakes by Individuals (CSFII). The study indicates that people in the U. S. eat both less total meat and beef as they grow older. Similarly based on CSFII data from 1994-96 and 1998, Davis and Lin (2005a) suggests that males in the U.S. aged over 39 and females aged over 19 consume less beef than previously, thereby per capita beef consumption is expected to fall over the next two decades as the population ages in U.S. Results from Canada based on the 2004 Canadian Community Health Survey (CCHS) indicate a significant reduction of average daily meat consumption after age 70 (Garriguet, 2004).

However, investigations on China's meat consumption, particularly the effects of population aging, are hindered by data availability. The official meat consumption data in China do not adequately include meat consumed away from home (MAFH) and are suspected of undercounting total meat consumption (Wang et al., 2004; Ma et al., 2006; Yu and Abler, 2014). As economic development, in general, and incomes, in particular, increase, the proportion of food consumed away from home (FAFH) in total household food consumption increases (Ma et al., 2006; Bai et al., 2010). This is particularly the case for MAFH as higher income households consume more pork, beef, and poultry away from home than lower income ones (Davis and Lin, 2005a,b; Yen et al., 2008). More accurate meat consumption data including MAFH are essential for studies related to meat and feed grain demand in China (Ma et al., 2004); otherwise, the results will undoubtedly be biased to some extent.

This paper empirically examines whether and to what extent demographic structure and population aging affect meat consumption in China. To do so, we utilize data of a large food consumption survey that includes household demographics, meat consumed at home (MAH), and MAFH. Firstly, we quantify per capita meat consumption by jointly considering MAH and MAFH. Secondly, we estimate the demand for meat that includes the impacts of demographic structure and population aging on household meat consumption. Finally, we simulate and discuss future meat demand in China based on this paper's estimated results, the literature, and trajectories of population in China. Compared to previous studies on meat consumption in China, this paper has several advantages. These include: 1) data that are from a household food consumption survey conducted in six Chinese cities (i.e., Beijing, Nanjing, Chengdu, Xi'an, Xiamen and Shenyang), that allow us to more accurately measure total meat consumption by all family members, both at home and away from home and to link meat consumption with household demographic structure; 2) the ability (first) to assess impacts of the proportion of senior population on meat consumption in China at the micro household level; and 3) the ability (first) to estimate China's future meat demand trend from the empirical analysis, the micro-level data, and projections of the trend of future population aging.

The rest of this paper is organized as follows. Section 2 describes the data used in this study and initial statistical analysis. In section 3, we present the empirical models that we use to estimate the impacts of demographic structure and aging on meat consumption. Further, the method of simulating meat demand trend under the trajectories of population in China is also introduced in this section. Section 4 presents the results of this study, and the last section concludes and discusses policy implications.

2. Data

The data were collected by interviewing 1340 urban households in six cities of China in 2007-2011 (figure 1). The samples in each city were stratified and randomly selected from the households participating in Urban Household Income and Expenditure (UHIE) survey conducted by NBSC[1]. The UHIE survey provides the primary official data on urban households' income and expenditures, but, regarding the FAFH data, it only provides annual per capita expenditure and does not include quantity of FAFH. Unlike the UHIE survey, our survey, through a week-long food diary approach (asking households to record all family members' food consumption for each meal), collected detailed food consumption data including FAFH and FAH. In addition, we also collected information on demographics of each family member, which can be directly linked to specific items of food consumption.

[1] It is widely agreed that that high-income households are under-represented in the UHIE survey because many refuse to participate in the survey. Given that our sampling frame relies on the UHIE pool, one needs to realize that our survey data may inevitably suffer from the same concern, although it is undeniable that the UHIE survey is the most representative and widely used household survey in China.

While the data are limited to that from the six cities, all six cities are national or regional centers of culture, economics, and transportation, so that consumers' preferences and food consumption patterns in these cities have significant influences in the regions in which they are located as well as on the entire nation (Bai et al., 2014). As such, the collected data provide the unique opportunity to analyze relevant food consumption issues in China. For instance, the dataset in Beijing was used in the studies by Bai et al. (2010), Bai et al. (2012); and Seale et al. (2012), and the dataset including Beijing, Nanjing and Chengdu was used in the study of Bai et al. (2014).

For this study, meat is defined to include pork, beef, mutton and poultry. It does not include other meats such as rabbit and donkey. Meat consumption at-home (MAH) and away-from-home (MAFH) are identified by whether the meats are consumed at home or whether they are consumed outside the home. Moreover, in order to facilitate the data presentation, the one week-long data has been simply converted into monthly data by the formula $, Meat\ consumption\ in\ a\ week/7 \times 30$. Note that this conversion does not affect the empirical results.

Table 1 reports the average meat consumption in the full sample and by city. It includes total meat consumption (TM), MAH, MAFH, and the percent of MAFH in TM. It should be noted that the surveys in Xi'an, Xiamen, and Shenyang took place in 2011 while those in the other three cities took place in earlier years. Nevertheless, given that meat consumption in China is still in the growth period, we can see that per capita average meat consumption in Beijing, Nanjing and Chengdu is greater than in the other three cities. In addition, as shown in table 1, MAFH accounts for a relatively large proportion of TM ranging from a low of 24% in Nanjing, Chengdu, and Xiamen to a high of 43% in Xi'an. The high proportion of MAFH in TM give an indication that meat consumption estimates not including MAFH would definitely underestimated TM consumption. Moreover, the results also suggest that the differences in TM and MAFH are significant among the six cities, which possibly is caused by the different levels of economic development, consumption preferences, and habits in these six cities. For instance, Chengdu, located in Sichuan province, has the highest per capita consumption of TM while Xi'an, located in Shaanxi province, has the lowest at 47% that of Chengdu. While this difference is large, the China Statistical Yearbook 2012 (National Bureau of Statistic of China, 2013) reports that per capita expenditure of meat in Shaanxi province is only 43% that in Sichuan province. Our survey also finds that Xi'an has the largest percentage of MAFH to TM among the surveyed cities. Xi'an is noted for the consumption of two local meat dishes, *Rou Jiamo* and *Bubble Steamed mutton/beef*, which are widely eaten away from home by consumer in Xi'an. Thereby, this unique food preference and habit in Xi'an leads to the highest percent of MAFH.

To descriptively show the potential effects of demographic structure on meat consumption, we divide the sample households into six types by age compositions of family members. The detail definitions are given in table 2, and per capita meat consumption by different family types is further drawn in figure 2 for the sake of clarification.

Apparently, per capita meat consumption is affected by family age composition. The existence of both young members (age≤16 years old) and elderly members (age>60 years old) has negative effects on per capita meat consumption in the household in comparison to the presence of mid-aged members (16<age≤60 years old). From figure 2, it is easy to see that the average per capita MAH consumption in type 1 families and type 2 families is slightly lower than other types of families. The existence of child in type 1 and type 2 families is likely the reason. However, when jointly considering MAFH and MAH, average per capita meat consumption in families composed only of mid-aged members (type 6) is the highest among the six types of families, reaching 5.5 kg/month/person. This is consistent with the study by Bai et al. (2010) where they show that both the number of children and the number of seniors in the household are significantly and negatively related to the probability of eating out, and households with more seniors also tend to spend less than those with fewer seniors if they dine out.

With an interest in the effects of population aging on meat consumption, we calculate and report per capita meat consumption by the proportion of seniors in the household (figure 3). The results illustrate that with the increasing proportion of seniors in the household, there is no significant change in MAH, but TM, MAFH, and the percent of MAFH in TM are all constantly declining. As shown in figure 3, households without seniors on average consume 5.35 kg of meat per month per person with MAFH constituting about 33% of TM. In contrast, when the proportion of seniors in the household is up to 2/3 and above, TM and the percent of MAFH decrease to 4.03 kg/month/person and 11%, respectively. Furthermore, the results of simple t-tests show that the differences of MAFH among the four groups are statistically significant while the group differences of MAH are insignificant. Further, the correlations between MAFH, MAH, TM and the proportion of seniors in household are measured with Spearman's correlation test. The results are similar with those of the t-tests, that is, MAFH has a significant and negative correlation with the proportion of seniors in household while there is no significant correlation between MAH and the proportion of seniors. These results indicate that the correlation between population aging and meat consumption in China is likely linear negative.

3. Methods

3.1 Econometric model specification

In order to capture the effects of population aging and demographic structure on meat consumption in China, we specify the following model,

$$y_i = \alpha_i + \sum_j \beta_{ij} X_j + \sum_k \gamma_{ik} Z_k + \delta_i D_c + \varepsilon_i \, , \tag{1}$$

where y_i is the dependent variable denoting per capita meat consumption on category i equals MAH, MAFH, or TM; X_j are a series of independent variables representing the household demographic structure as measured by the proportion of different age groups; vector Z_k represents the other socioeconomic and demographic variables affecting household meat consumption; D_c is a set of city dummy variables; α_i, β_{ij} , γ_{ik} and δ_i are parameters to be estimated; and ε_i is the error term. Notice that there are no price variables in this meat consumption function. This is because meat consumption in this study is defined as the combination of pork, beef, mutton and poultry, which makes it difficult to measure the price of meat. Yen et al. (2008) argues that, in the absence of price information, the use of urbanization, regional, and seasonal variables is especially important as they might reflect variations in prices. As the data used in this study were collected in only cities and almost in the same period (from July to September) in the survey years, we only need to consider the regional variation of price in the model specification. In this study, we use the city dummies to control for regional differences of meat price and other unobserved city variations related to meat consumption.

The estimations of function (1) are as follows. We apply ordinary least squares (OLS) linear regression for the TM (i.e., y_{TM} as dependent variable) function while employing seemingly unrelated regressions (SUR) for models y_{MAH} and y_{MAFH} jointly, considering ε_{MAH} and ε_{MAFH} are likely contemporaneously correlated (Zellner, 1962). The correlation between error terms can be tested using a χ^2 statistic - Lagrange multiplier statistic suggested by Breusch and Pagan (1980). If the result of the Breusch-Pagan test of independence cannot be rejected, it implies that the error terms of the two functions are uncorrelated, and y_{MAH} and y_{MAFH} will be separately re-estimated using OLS. In addition, a Wald statistic is used to test the joint significance of X_j, the demographic structure variables.

The independent variables included in X_j, Z_k and D_c are shown in table 3. The demographic structure variables are valued by the proportions of six different age groups in the household. Similar household age composition variables are used in Vardges and Gould (2011). The estimated parameter of the proportion of family members aged over 60 years old will be used as an index for measuring the impact of population aging on meat consumption; we define it here as β_6 to be used in the continuance simulation analysis. The variables "characteristics of households" consist of household size, household income, and the proportion of males in the household, variables that have had significant effects on meat consumption in previous studies (Wang et al., 2004; Liu et al., 2009; Liu et al., 2011). The term "planners" used in table 3 refers to persons in the households that are the direct decision makers of food shopping and food preparation, and characteristics of these planners are often found to have significant effects on household food consumption. Because typically most of the food planners in China are female (Bai et al., 2014), the gender variable is also included in this study. To control for other effects of planners, we also include their age, ethnicity, and education level (Liu et al., 2009; Vardges and Gould, 2011). Additionally, we include city dummy variables as discussed above.

3.2 Simulation of meat demand trend in China before 2030

Based on the regression analysis discussed above, we estimate the parameter β_6 that denotes the impact of population aging on meat consumption. It will be used to simulate the future trend in China's meat consumption, under the trajectories of population in China. If the proportion of population aged over 60 years old increase 1%, per capital meat consumption will change *by* θ% which can be calculated by the formula:

$$\theta = (\beta_6 / mean\ of\ per\ capital\ meat\ consumption) \times 100\% \quad (2)$$

Given the rapid urbanization in China and the strong representative nature of the data of the six survey cities, the effect θ is assumed to be national wide. In addition, both meat consumption and population aging in China are assumed to increase continuously in coming years, propositions that have widespread agreement in previous studies (Xie, 2004; Du et al., 2005; Fu et al., 2012; Zhou et al., 2012; Peng, 2011; Flaherty et al., 2007; Yang, 2007; Wang and Wang, 2011; United Nations, 2013). Therefore, we assume in the coming year t that the per capita meat consumption growth rate compared to year $t\text{-}1$ is v_t ($v_t > 0$), and the proportion of elderly population (aged>60) increases μ_t percent ($\mu_t > 0$). Thus, the expected per capita meat consumption in year t (Q_t) without considering population aging is expressed as

$$Q_t = (1 + v_t) \times Q_{t-1} \quad (3)$$

while the per capita meat consumption considering population aging (Q_t') is calculated by adding the extra effect of population aging change on meat consumption from year $t\text{-}1$ to year t as following:

$$Q_t' = (1 + v_t) \times Q_{t-1}' + \theta \times \mu_t \times Q_{t-1}' . \quad (4)$$

Assume the number of people in China in year t is P_t, then the expected meat consumption with or without considering population aging in China is calculated by the simple formulas $P_t \times Q_t$ and $P_t \times Q_t'$, respectively.

In addition, to better capture the relations between Q_t and Q_t', we use formula (3) minus formula (4) for obtaining the expected error (u_t) of per capita meat consumption due to not considering population aging. The formula for calculating u_t is defined and derived as follows:

$$u_t = Q_t - Q_t' \ . \tag{5}$$

Formula (3) and formula (4) are introduced into formula (5) such that

$$u_t = (1 + v_t) \times (Q_{t-1} - Q_{t-1}') - \theta \times \mu_t \times Q_{t-1}' \tag{6}$$

where in ($Q_{t-1} - Q_{t-1}'$) can be expressed as u_{t-1}, which is deduced from formula (5). Thus, formula (6) is transformed as,

$$u_t = (1 + v_t) \times u_{t-1} + (-\theta) \times \mu_t \times Q_{t-1}' \ . \tag{7}$$

The assumptions of v_t (v_t >0) and μ_t (μ_t >0) suggest (1+ v_t) >1 and ($\mu_t \times Q_{t-1}'$) >0, so formula (7) implies that the relation between u_t and u_{t-1} is determined by θ. Based on the three possible value ranges of θ, the respective relations between u_t and u_{t-1} are different. For instance: a) in the case of θ=0 (i.e., population aging does not affect meat consumption), the error of expect meat consumption without considering population aging is zero ($u_t = u_{t-1} = 0$); b) in the case of θ>0 (i.e., population aging improves per capita meat consumption), the relation between u_t and u_{t-1} is uncertain. In such a case, the relation between u_t and u_{t-1} is jointly determined by the specific value of v_t and μ_t as well as θ; and c) in case of θ<0 (i.e., the impact of population aging on meat consumption is negative), then $(-\theta) \times \mu_t \times Q_{t-1}' > 0$ indicating $u_t > u_{t-1}$.

Case c) is further drawn in figure 4. Based on the hypothesis that population aging negatively impacts growth of per capita meat consumption in China, the growth of Q_t' represented by the dashed line in figure 4 is more gentle than Q_t (solid line), which implies population aging in China reduces the increasing trend of meat consumption to some extent. Moreover, the gradually expanding gaps between Q_t and Q_t' illustrate that if the aging factor is not considered, expected per capita meat consumption in China will be more and more over-estimated, meaning the longer the predicted period, the greater the estimated error.

Data for simulating future per capita meat demand trends under the situation of population aging in China are collected from two previous studies. Expected per capita meat consumption data without considering population aging are from Zhou et al. (2012), and population trajectries data are from Du et al. (2005). While other projected data of meat consumption in China are available the USDA, OECD-FAO or other similar departments (Zhou et al., 2012), the expected data of Zhou et al. (2012) and Du et al. (2005) are more suitable for our simulation. Zhou et al. (2012) provide the details of their simulation method allowing us to extend their forecast until the year 2030. Further, as the simulated data of Zhou et al. (2012) do not account for population aging effects, we can use them directly for our simulation purposes of measuring the forecasting error of future Chinese meat consumption when one does not account for population aging. We do so through the formulae above with the Q variables being represented by the quantity data of Zhou et al. (2012) and the P variables being represented by population data of Du et al. (2005). The population trajectories of Du et al. (2005) are chosen based on considerations of the authors' professional experiences on studying China's population issues. In a few cases, there are omissions in these data, and we use simple interpolation to obtain values for the omissions. Table 4 presents the summary of the final data used in our simulation. Note that Zhou et al. (2012) extrapolate their data based on the assumption of 8% growth in gross domestic product (GDP) and a linear relationship between per capita meat consumption and income.

In addition, based on the estimated results of TM, we propose another projection for urban household meat consumption from 2010 to 2030. Firstly, we assume that meat consumption of urban household in China can be forecasted using the model of TM. Then, for capturing the differences in meat consumption projections with or without considering population aging effect, we make two sets of assumptions: (1) assume the variables *Age>60* and *income* are changing, while the other factors are constant in the model TM; (2) assume only the variable *income* is changing, whereas the other factors including *Age>60* are constant. Thus, the projection results of assumption (1) and (2), respectively, reflect meat consumption considering population aging and without considering population aging. Furthermore, for simulating these two projections, the population trajectory data in table 4 are utilized again. The data on income trends includes two parts: the data from 2010 to 2013 are from *China Statistic Yearbooks*; and the income data of the remaining years are calculated by assuming a constant rate of increase in urban household income of 3%, 5%, 8%, and 10%, respectively.

4. Results

Table 5 reports the estimation results. To account for the likely correlation between the error terms of the MAFH and MAH equations, we estimate the two equations by SUR. The Breusch-Pagan test rejects the null hypothesis of no correlation at the 1% significant level, indicating the MAFH and MAH equations should be estimated jointly. As for the TM equation, OLS regression is used directly. F-Statistics of all estimated equations are significantly different from zero, meaning that all explanatory variables have significant joint explanatory power. Also, most independent variables are statistically significant with the expected signs and reasonable magnitudes.

The Wald test reported in table 6 rejects the null hypothesis at the 1% significance level, indicating that the variables of family demographic structure taken together have a statistically significant effect on per capita meat consumption. However, the effects of demographic structure on MAFH, MAH and TM are remarkably different. For example, in terms of MAH, none of the coefficients on the demographic structure variables are statistically different from zero. In contrast, almost all coefficients of demographic structure variables for MAFH are significantly different from zero, and their signs are negative. This suggests that an increase in the proportion of population aged 16 and below as well as over 40 leads to a decline in per capita MAFH. For TM, the effects of population aged 16 and below disappear, but the proportion of population aged 50 and above has significant and negative effects on TM. These results demonstrate that population aging in China negatively impacts per capita meat consumption. In addition, from the coefficients of the different demographic variables, the proportion of elderly (age>60) in the household has the largest negative effects on per capita total meat consumption ($\beta_6 = -0.025$). The calculated elasticity estimate from equation (2) indicates that, if the proportion of population aged over 60 in household increases by 1%, household per capita total meat consumption declines by 0.5% (θ = -0.005).

Other socioeconomic and demographic characteristic variables have statistically significant impacts on household per capita meat consumption. For example, household size has a negative effect on MAH and TM. This result differs from Bai et al. (2012) where household size presents significant and positive effects on the probability of dining out for lunch and dinner as well as the conditional expenditure level for lunch away from home. Statistically significant coefficients on income and income squared in the MAFH and TM equations are positive and negative, respectively, indicating that per capita consumption of MAFH and TM increases with income at a decreasing rate. The respective income terms in the MAH equation have the same signs, but they are not statistically significant. These results are consistent with the study of Guo et al. (2000), but differ somewhat from the study of Wang et al. (2004) who find that meat consumption increases linearly with increasing income. Moreover, our results also suggest that households with more males consume more meat both at-home and away-from-home.

Regarding characteristics of planners, only their age and education are significantly related to per capita meat consumption. The planer's age has a significant and nonlinear effect on household per capita consumption of MAH and TM in the shape of an "inverted U". The respective turning point for MAH and TM is 62 years old and 58 years old, respectively. This implies that household per capita consumption of MAH decreases when a planner's age increases beyond 62 years old. In addition, although MAFH is not significantly affected by the age of planners, the turning point of the planner's age has declined from 62 for MAH to 58 for TM due to the combining of MAFH to MAH. This is mainly driven by the unbalanced distribution of MAFH when taking into account the planner's age. According to our calculation, the mean of MAFH consumption is 1.7kg/month for planners aged below 58 years old and 0.8 kg/month for planners aged above 58 years old. Thereby, the relatively high MAFH consumption when planner's age<58 pulls the turning point of TM below that of MAH, down to 58 years old from 62 years old. Thus, although the demographic structure variables do not have a significant effect on MAH, population aging has a negative effect on MAH through the aging of household planners. Households with planners holding college and advanced education levels are found to consume more MAFH than other households.

Utilizing the parameter estimates above, future per capita consumption of meat in China is simulated from 2010 to 2030 taking into account the significant and negative impact of population aging on per capita meat consumption (column 3, table 7). Next, our simulated results are compared to those in column 2, table 7, of Zhou et al. (2012) that do not account for population aging effects. As expected, the future simulated trend of meat demand in China that does not consider the effects of population aging is greater than one that does, and the difference between the two simulations as measured by u_t grows over time as population aging increases.

By multiplying these simulated per capita quantities by the population projections of Du et al. (2005), two series of total Chinese meat consumption measured in millions of tons are calculated, one that does not account for population aging (column 5, table 7) and another that does (column 6, table 7). The former overestimates total meat consumption in China on an annual bases that starts at 0.2 million tons in 2011 and increases to 8.2 million tons in 2030 (column 7, table 7). In percentage terms, the projection not accounting for population aging effects overestimates total meat consumption by almost 6% by 2030. While the annual errors may not seem large, the cumulative errors are. Over the 20-year period, projections not accounting for population aging overestimate total meat demand in China by 66 million tons.

Figure 5 demonstrates the projected trends of urban household meat consumption based on this study's parameter estimates on income and population aging and the different assumptions about increasing income rates. In terms of the quantity of meat consumption, the results are smaller than the above simulation. The highest per capita meat consumption occurs around 74 kg/year/person without considering population aging. When considering population aging, the highest meat consumption is less than 70 kg/year/person. This suggests that population aging has a significant negative effect on per capita meat consumption. Besides, comparing the four parts of figure 5, we find that the urban household meat consumption trend is dominantly driven by household income. If the rate of income growth is 5% or less, meat consumption will continue to increase through 2030. However, if income constantly grows at the current rate (approximate 9-10% in 2013) urban household meat consumption will reach its turning point around 2025.

It is noticed that the projected per capital meat consumption based on our estimation is significantly lower than that based on the results of Zhou et al. (2012). There are at least two possible reasons rather than data differences. Firstly, considering the negative effects of population aging on meat consumption is apparently an important explanation to the difference. Second, the projected method used in Zhou et al. (2012)

led to a continuous increase in per capita meat consumption, which could accordingly overestimate the predicted results.

5. Concluding remarks

China has experienced rapid economic growth over the last three decades. This growth has led to a substantial improvement in people's living standards and reduction in poverty, but it has also led to massive increases in the production of agricultural products (Sutherland and Yao, 2011). Additionally, the population structure in China is rapidly changing with an increasing proportion of the population being elderly, and this ageing trend is expected to continue into the future. These economic and societal changes have potentially important implications concerning future food security in China. As the aging of China's population is inevitable, measuring and accounting for its effects on food consumption, particularly meat consumption, is essential in terms of agricultural planning and agricultural import policy. Although the quantity of grain consumed per person is decreasing as incomes have increased, per capita meat consumption is increasing. Because meat production is generally a grain intensive activity, it is possible for grain consumption to increase as the number of animals for meat production increases even while people eat less grain directly.

This paper examines the impact of population aging on meat consumption in China by jointly considering MAH and MAFH by using recently collected urban household food consumption data from six cities in China and by simulating the meat demand trends under the trajectories of population growth and aging. Its major findings are as follows. Firstly, the inclusion of MAFH is essential for studies on China's meat demand. Our survey results suggest MAFH, which is not adequately accounted for in official meat statistics, comprises nearly 30% of total household meat consumption. Secondly, the empirical analysis finds that the demand for MAH and MAFH are affected differently by household demographic structure. Specifically, we found no statistically significant effect of house demographic structure on MAH demand, but we did for MAFH, particularly in terms of the existence of children and seniors in the household. When including both MAH and MAFH in TM, the household demographic structure has significant effects on TM demand. These results suggest care must be taken when extrapolating from meat demand studies that do not include

MAFH consumption to total meat demand. Our findings also help explain why many previous studies have not found significant effects of population aging on meat demand as most are based on data that do not include MAFH quantities. Thirdly, population aging negatively affects per capita meat consumption in urban China. If the proportion of elderly population increases 1%, the quantity of meat consumption per capital will decrease 0.5%. In addition, the simulation result suggests that the expected meat demand without considering population aging is overestimated, and longer predicted periods will lead to greater estimated error. These findings are important for those interested in meat demand forecasting and its future effects on meat production in China, meat imports into China, and food security issues related to grain demand and supply, particularly under the future and increasing population aging of China’s society.

This study does have inevitable limitations. For instance, using panel data would improve our ability to estimate the effects of population aging on meat consumption over our use of cross-section data. However, to our knowledge no panel data exist at the micro level that includes quantities consumed of MAH and MAFH. Also, our simulation analysis relies on the important assumption that meat consumption behavior of individuals changes as they age. It is commonly held that elderly people in China pay more attention to health effects of consumption than youths do, resulting in obtaining fewer calories from meat in order to avoid diseases caused by excessive fat. The results found in this study also support this premise, and thus the assumption is probably an accurate portrayal of Chinese society. Hence, given our findings, the topic of population aging and its effects on food demand in China warrants further study.

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Table 1 Meat consumption by city (kg/month/person)*

City	TM	MAH	MAFH	Percent of MAFH
All samples	5.06	3.58	1.48	29%
Beijing	5.67	3.79	1.88	33%
Nanjing	5.42	4.10	1.32	24%
Chengdu	6.60	5.01	1.59	24%
Xi'an	3.20	1.81	1.39	43%
Xiamen	4.58	3.46	1.12	24%
Shenyang	4.46	3.18	1.28	29%

*TM=total meat; MAH= meat consumed at home; MAFH= meat consumed away from home.

Table 2 Family types clustered by age composition of family members

Family Type	Definition	Number of Households
Type 1	Composed of young and mid-aged members only	332
Type 2	Composed of young and elderly members only	20
Type 3	Composed of elderly members only	110
Type 4	Composed of all age groups of members	113
Type 5	Composed of mid-aged and elderly members only	149
Type 6	Composed of mid-age members only	616

*Young denotes member aged 16 years old or under; mid-age denotes member aged between 17 and 60 years old; elderly denotes member aged above 60 years old.

Table 3 Descriptive statistics of independent variables

Independent variables	Mean	Std. Dev.	Min	Max
X_j *Demographic structures (%)*				
Proportion of members aged≤16 in household	10.84	15.45	0	66.67
16<Age≤ 30	16.02	20.57	0	100
30<Age≤ 40	13.38	23.79	0	100
40<Age≤ 50	20.24	28.27	0	100
50<Age≤ 60	22.64	32.26	0	100
Age>60	16.88	30.64	0	100
Z_k *Other socioeconomic and demographic variables*				
Characteristics of households:				
Household size	2.91	0.87	1	7
Income (1000 Yuan/month/person)	1.99	1.26	0.17	15.8
Proportion of male (%)	49.87	17.90	0	100
Characteristics of household food consumption planners:				
Age (years)	50.45	12.09	16	87
Gender（1=male；0=female）	0.38	0.49	0	1
Ethnicity（1=Han；0=otherwise）	0.97	0.17	0	1
Education (Dummy variable)				
Middle school and below (1=middle, 0=otherwise)	0.29	0.45	0	1
High school (1=high, 0=otherwise)	0.29	0.46	0	1
Vocational college (1=vocational, 0=otherwise)	0.24	0.43	0	1
Bachelor and above (1= bachelor, 0=otherwise)	0.17	0.38	0	1
D_c *Dummy variables of survey cities*				
Beijing (1=Beijing, 0=otherwise)	0.24	0.42	0	1
Nanjing (1=Nanjing, 0=otherwise)	0.18	0.39	0	1
Chengdu (1=Chengdu, 0=otherwise)	0.16	0.36	0	1
Xi’an (1=Xi’an, 0=otherwise)	0.16	0.37	0	1
Shenyang (1=Shenyang, 0=otherwise)	0.15	0.36	0	1
Xiamen (1=Xiamen, 0=otherwise)	0.11	0.31	0	1

Data source: Authors’ survey

Table 4 Summary of data for simulation

Year	Per capita meat consumption*		Population		
	(kg/year/person)	Growth rate	(billion)	proportion of population	
t	Q_t	v_t	P_t	aged 60+	μ_t
2010	59.50	0.00	1.36	12.71	0.00
2011	61.60	0.04	1.37	13.21	0.50
2012	63.60	0.03	1.38	13.71	0.50
2013	65.70	0.03	1.39	14.21	0.50
2014	68.00	0.04	1.39	14.71	0.50
2015	70.20	0.03	1.40	15.17	0.46
2016	72.60	0.03	1.41	15.53	0.36
2017	74.90	0.03	1.42	15.88	0.36
2018	77.50	0.03	1.42	16.24	0.36
2019	80.00	0.03	1.43	16.60	0.36
2020	82.70	0.03	1.43	16.96	0.36
2021	84.36	0.02	1.44	17.61	0.65
2022	86.65	0.03	1.44	18.26	0.65
2023	88.95	0.03	1.44	18.91	0.65
2024	91.24	0.03	1.44	19.56	0.65
2025	93.53	0.03	1.45	20.21	0.65
2026	95.82	0.02	1.44	20.99	0.78
2027	98.12	0.02	1.44	21.76	0.78
2028	100.41	0.02	1.44	22.54	0.78
2029	102.70	0.02	1.44	23.32	0.78
2030	104.99	0.02	1.44	24.10	0.78

Data source: Zhou et al. (2012) and Du et al. (2005)

Notes: *includes pork,beef,mutton and poultry

Table 5 Estimation results

	MAFH			MAH			TM		
	Coef.	Std. Err.		Coef.	Std. Err.		Coef.	Std. Err.	
X_j *Demographic structure (%)*									
Age≤16	-0.017	0.005	***	0.006	0.007		-0.010	0.008	
16<Age≤ 30	-0.002	0.003		-0.0001	0.004		-0.003	0.005	
30<Age≤ 40				Omitted					
40<Age≤ 50	-0.008	0.003	***	0.003	0.004		-0.005	0.004	
50<Age≤ 60	-0.017	0.003	***	0.003	0.004		-0.014	0.004	***
Age>60	-0.020	0.003	***	-0.004	0.005		-0.025	0.005	***
Z_k *Other socioeconomic and demographic variables*									
Characteristics of households:									
Household size	-0.084	0.059		-0.189	0.081	**	-0.273	0.094	***
Income	0.378	0.077	***	0.110	0.107		0.488	0.124	***
Income^2	-0.027	0.008	***	-0.010	0.011		-0.037	0.013	***
Male (%)	0.006	0.002	**	0.007	0.003	**	0.013	0.004	***
Characteristics of household food consumption planners:									
Age	0.038	0.029		0.112	0.040	***	0.150	0.046	***
Age^2	-0.0004	0.0003		-0.0009	0.0004	**	-0.0013	0.0004	***
Gender	0.079	0.100		-0.117	0.139		-0.038	0.161	
Ethnicity	0.010	0.251		0.123	0.348		0.134	0.402	
Education (Dummy variable)									
Middle school				Omitted					
High school	0.151	0.116		-0.006	0.161		0.145	0.186	
College	0.408	0.124	***	0.094	0.172		0.502	0.199	**
Bachelor	0.275	0.147	*	-0.007	0.204		0.268	0.235	
D_c *Dummy variables of survey cities*									
Beijing				Omitted					
Nanjing	-0.441	0.134	***	0.445	0.187	**	0.004	0.216	
Chengdu	-0.075	0.147		1.227	0.204	***	1.153	0.236	***
Xi'an	-0.436	0.144	***	-1.991	0.200	***	-2.427	0.230	***
Shenyang	-0.405	0.146	***	-0.589	0.203	***	-0.994	0.234	***
Xiamen	-0.741	0.164	***	-0.280	0.227		-1.021	0.262	***
Constant term	1.186	0.761		0.388	1.058		1.573	1.221	
Obs.	1340			1340			1340		
R-sq/ Adj R-sq	0.18			0.19			0.21		
F-Statistics	13.68			14.44			17.97		
Prob > F	0.000			0.000			0.000		
Correlation coefficient of residuals	-0.1443								
Breusch-Pagan test of independence	Chi^2(1) = 27.896***								

Notes: Significant level *P<0.1, **P<0.05, ***P<0.01

MAFH= meat consumed away from home; MAH= meat consumed at home; TM= total meat consumed.

Table 6 Wald-test of the effects of demographic structure on meat consumption

Models	Null hypothesis	Wald-statistics
MAFH&MAH	Coefficients of demographic structure variables	6.71 ***
TM	jointly equal zero	5.94 ***

Notes: Significant level **P*<0.1, ***P*<0.05, ****P*<0.01

Table 7 Simulation results

Year	Per capita meat consumption (kg/year/person)			Meat demand in China (Million ton)			Percent of overestimation
t	Q_t	Q_t'	u_t	$P_t \times Q_t$	$P_t \times Q_t'$	$P_t \times u_t$	(%)
2010*	59.50	59.50	0.00	80.98	80.98	0.00	0.00%
2011	61.60	61.45	0.15	84.34	84.14	0.20	0.24%
2012	63.60	63.29	0.31	87.60	87.18	0.42	0.49%
2013	65.70	65.22	0.48	91.04	90.38	0.66	0.73%
2014	68.00	67.34	0.66	94.79	93.88	0.91	0.97%
2015	70.20	69.37	0.83	98.56	97.39	1.17	1.20%
2016	72.60	71.62	0.98	102.37	100.98	1.39	1.37%
2017	74.90	73.76	1.14	106.07	104.45	1.62	1.55%
2018	77.50	76.19	1.31	110.22	108.35	1.87	1.72%
2019	80.00	78.51	1.49	114.26	112.13	2.13	1.90%
2020	82.70	81.02	1.68	118.51	116.10	2.41	2.08%
2021	84.36	82.38	1.98	121.09	118.25	2.85	2.41%
2022	86.65	84.35	2.30	124.59	121.28	3.31	2.73%
2023	88.95	86.31	2.64	128.10	124.30	3.80	3.06%
2024	91.24	88.25	2.99	131.62	127.31	4.31	3.39%
2025	93.53	90.18	3.35	135.15	130.32	4.84	3.71%
2026	95.82	92.04	3.78	138.45	132.98	5.46	4.11%
2027	98.12	93.89	4.23	141.74	135.63	6.11	4.50%
2028	100.41	95.72	4.69	145.03	138.25	6.78	4.90%
2029	102.70	97.53	5.17	148.32	140.85	7.47	5.30%
2030	104.99	99.33	5.67	151.61	143.43	8.18	5.71%

Notes: *base year

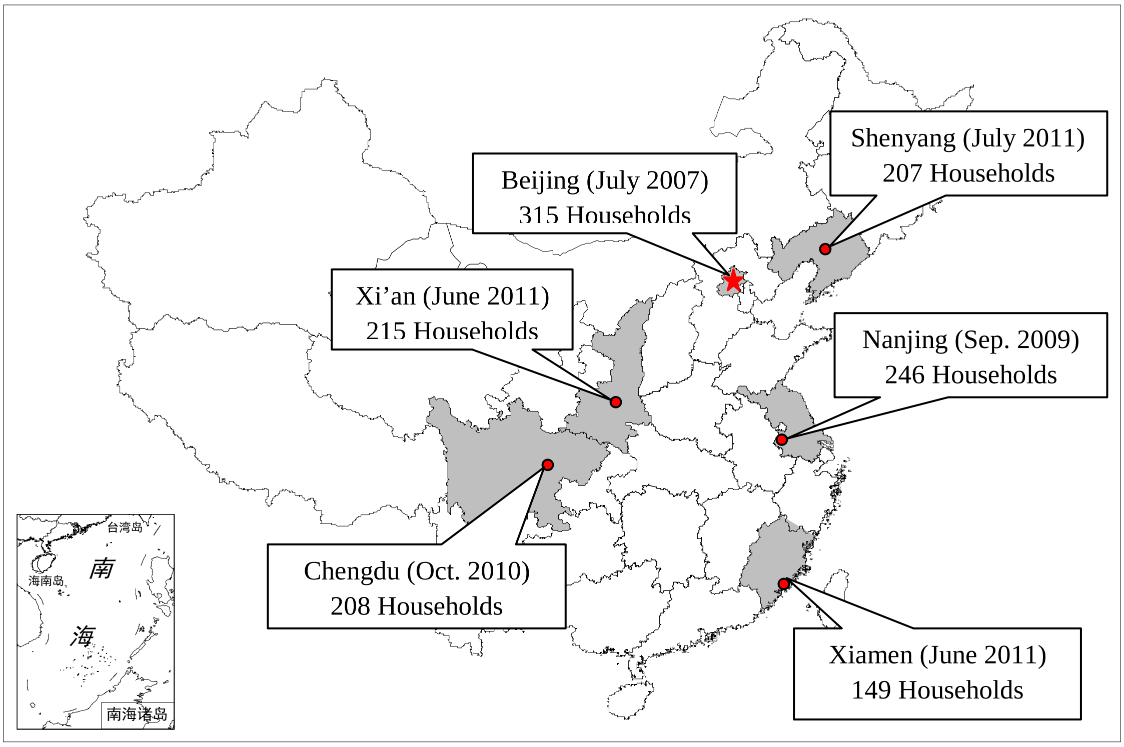

Fig.1 Sample cities distribution of food consumption survey in China

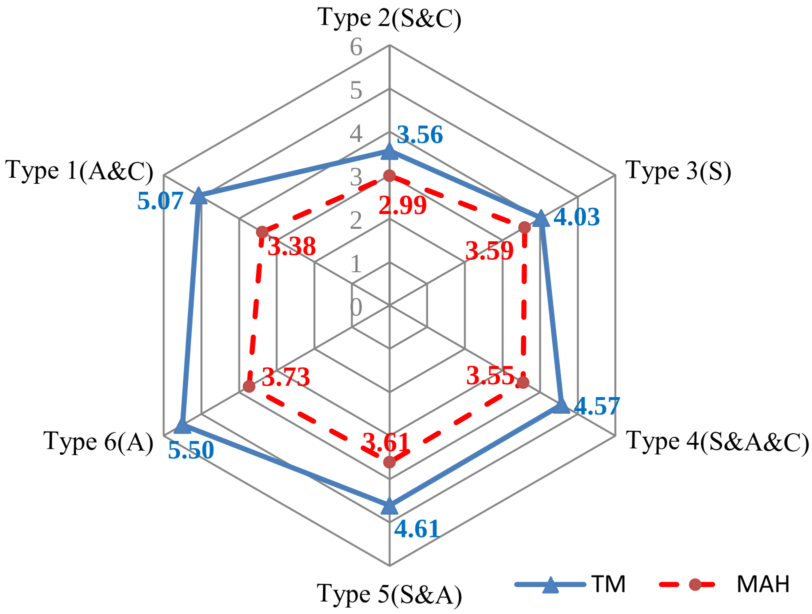

Fig.2 Meat consumption by demographic structure (kg/month/person)

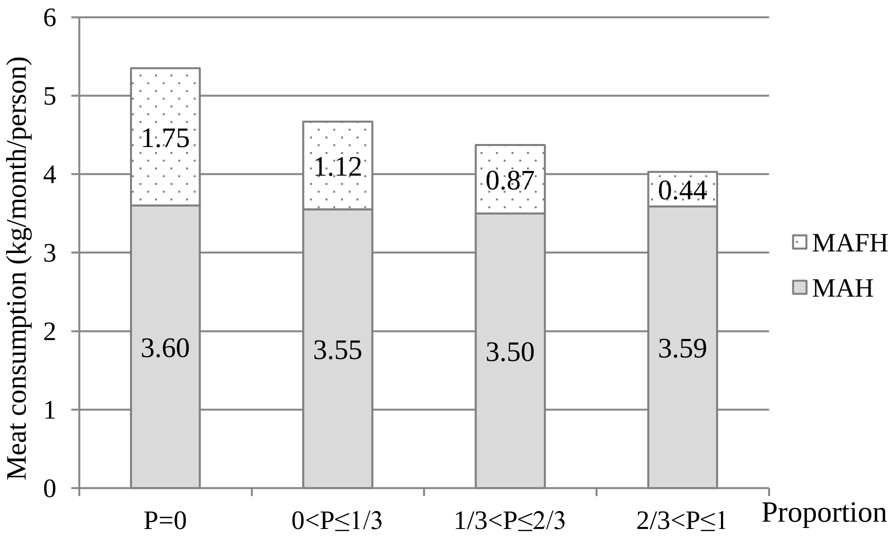

Fig. 3 Meat consumption by proportion of seniors in household (kg/month/person)

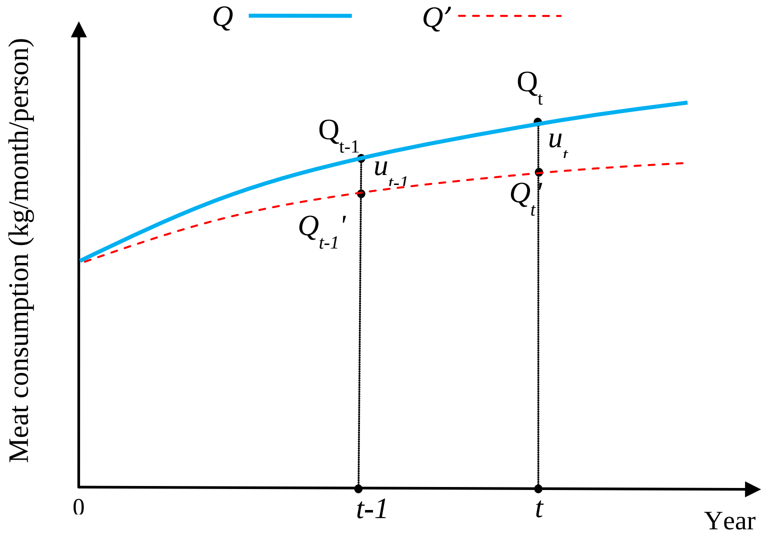

Fig. 4 Per capita meat consumption trends in China

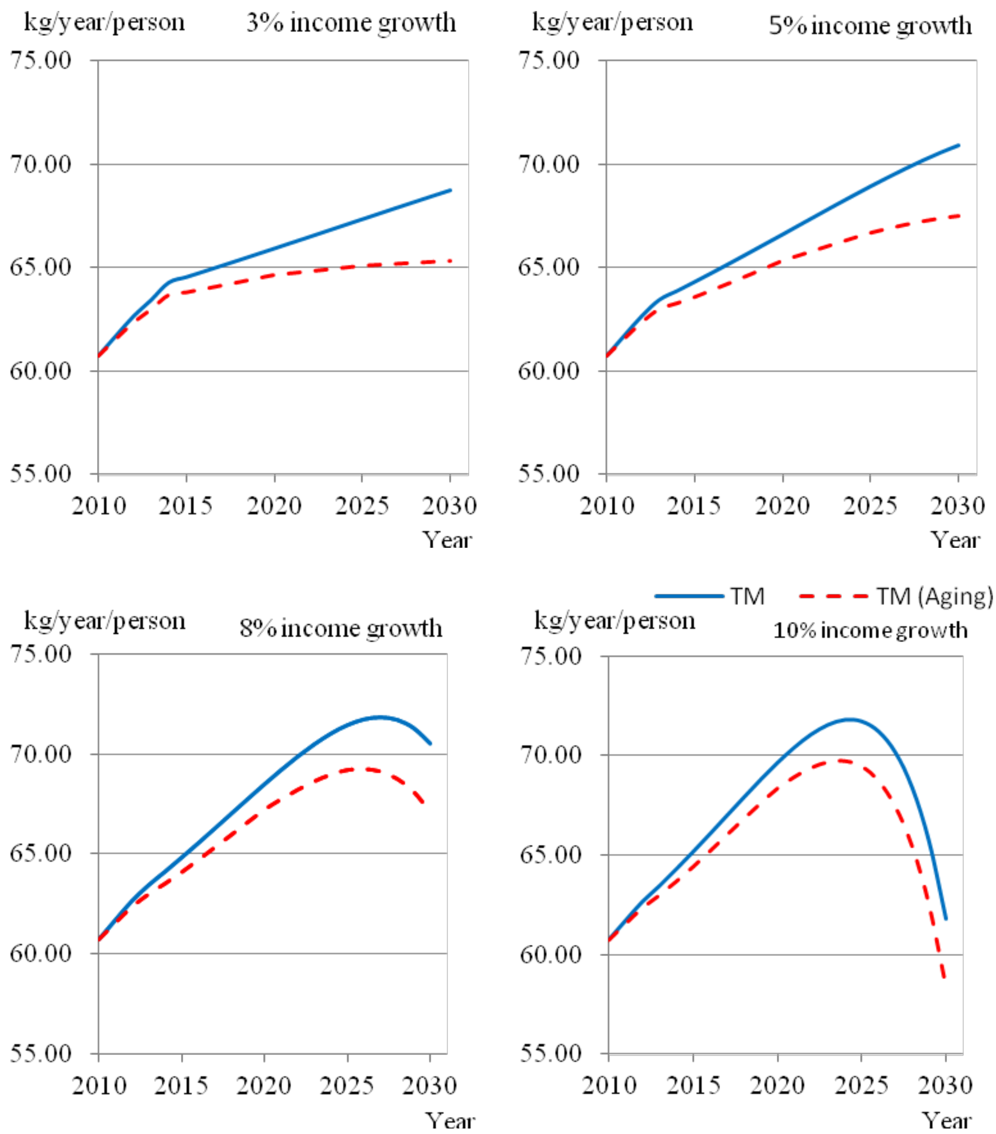

Fig. 5 Projected meat consumption trends for urban households