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# Meat demand in China: to include or not to include meat away from home?\*

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This study examines meat consumption in China, the world's largest meat consumer and producer, by considering both meat consumed at home and away from home based upon a diary-based household survey. The results indicate that income growth leads to beef, poultry, other meat and pork away from home consumption to grow more than proportionally to total meat consumption. We also find that meats consumed away from home grow faster than at home counterparts due to higher income elasticities, suggesting that ignoring meat away from home could significantly underestimate current and future meat consumption.

**Key words:** demand analysis, consumer demand, China.

## 1. Introduction

Meat demand in China, the world's largest meat consumer and producer, influences the meat and feed use grain markets inside and outside of the nation. As in many other countries, income growth and urbanisation have shifted Chinese diets away from one centred on staples to those that incorporate more animal protein products. In the past, the increasing meat demand could largely be satisfied by domestic production (Li *et al.* 2013; Fukase and Martin 2014). The situation, however, has changed since 2009, when China turned from a net corn exporter into a net corn importer because of the strong demand for feed grain and the limited domestic natural endowment. Therefore, whether China can sustain a high self-sufficient rate for meat products in the future becomes a question of concern. The recent trade tension between the United States and China, along with the rapidly spreading African Swine Fever and the rising desire for sustainable agriculture in China, makes the concern more crucial. An improved understanding of China's changing meat demand and its trends can provide

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critical information on sustainable self-sufficiency in meats and its effect on the environment.

To understand meat demand in China, one must account for the remarkable growth in dining out. Numerous studies from developed countries have shown that household dining out increases significantly with income growth (Byrne *et al.* 1996; Mutlu and Gracia 2006). Further, the proportion of meat consumption in dining out consumption is comparatively higher than it is in food consumption at home (Byrne *et al.* 1996). In China, dining out consumption is also increasing, particularly in urban areas, due in part to rapid increases in income growth and in urbanisation (Min *et al.* 2004; Ma *et al.* 2006; Liu *et al.* 2012; Bai *et al.* 2016). Therefore, without considering meat consumption while dining out, any estimation of income or expenditure elasticities of meat consumption or any projections based on these could cause one to misunderstand of the actual situation (Bai *et al.* 2016).

Unfortunately, the existing literature examining food consumption in China gives little attention to meat consumed away from home (MAFH). Ma *et al.* (2006) found that income growth increases MAFH demand and affects the composition of expenditure. Households tended to spend more on meat and fish when they dine out than when they dine at home. Bai *et al.* (2012) and Xiao *et al.* (2015) studied China's household dining out consumption and concluded that the officially reported statistics for meat consumption in China may be significantly underestimated. Min *et al.* (2004) used macro-level data to estimate the income effects on household dining out expenditure, but they did not pay specific attention to MAFH. Other studies on China's food consumption in general only focus on food at home (FAH) consumption (Wang and Chern 1992; Fan *et al.* 1995; Gao *et al.* 1996; Huang *et al.* 1999; Guo *et al.* 2000; Liu *et al.* 2009; Ortega *et al.* 2009; Dong and Fuller 2010). An explanation for this is that most studies utilise data from the National Bureau of Statistic China (NBSC) that only include total expenditure on dining at home (Ma *et al.* 2004; Bai *et al.* 2010).

In this study, we re-examine meat consumption in China by considering both MAH and MAFH. Our data were collected through a diary-based household survey in nine Chinese cities and provide a unique opportunity to conduct this study. In the survey, the sampled households were asked to record detailed information on food consumption by household members' meal-by-meal, including at home and away from home, for an entire week. This enables us to estimate the demand for meats consumed at home (i.e. pork, beef, poultry and other meat) as well as for the same meats consumed away from home. We fit a two-stage quadratic almost ideal demand system (QUAIDS) to the survey data of these eight meat categories. To our knowledge, this is the first study to estimate demand for both MAH and MAFH by types of meats (i.e. pork, beef, poultry and other meats). Also, the detailed information in our survey enables us to link meat consumption to household composition in terms of age structure and household-member

health. Linking these variables to the observed meat consumption allows us to identify driving forces in addition to prices and expenditures in terms of meat demand patterns.

The key results indicate that income growth leads to beef, poultry, other meat (including mutton and offal) and pork away from home consumption to grow more than proportionally to total meat consumption, suggesting a potential growth market for these meats. We also find that all four of the meat types consumed away from home will grow faster than their counterpart consumed at home. These results suggest that excluding MAFH could significantly underestimate current meat consumption as well as meat demand projections.

The structure of the paper is as follows. Section 2 describes in detail the survey and the data construction. Section 3 presents the method and empirical model development. Section 4 discusses the empirical results and demand elasticities. Section 5 concludes with major finding remarks and policy implications.

## 2. Survey and data description

### 2.1 Survey description

The data for this study were collected by surveying 2,027 urban households in nine cities from 2010 to 2012. These cities are Nanjing in Jiangsu province; Chengdu, in Sichuan province; Xi'an in Shaanxi province; Shenyang in Liaoning province; Xiamen in Fujian province; Taiyuan in Shanxi province; Harbin in Heilongjiang province; Nanning in Guangxi province; Lanzhou in Gansu province; and Taizhou in Zhejiang province.<sup>1</sup> For the sake of regional comparison, we restricted the survey time between July and September of each survey year.

The household samples in each city are a subset of the households that were participating in the Urban Household Income and Expenditure (UHIE) survey conducted by the NBSC in the city. The UHIE survey provides the primary official information on urban consumers' income and expenditures and is a primary data source of the published China Statistical Yearbooks. On food consumed away from home, the UHIE survey, however, only includes total expenditure, which does not allow us to use these data for this specific study. In each city, we first selected three or four districts from the metropolitan area through discussions with the experts in charge of the UHIE survey in the city. The overall income level of residential households in each district and the geographic location was jointly considered for the district selection for a better representation of our sample. We then proportionally

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<sup>1</sup> We also conducted the survey in Beijing in 2007 and in Nanjing in 2009. However, considering the time difference, we excluded Beijing and Nanjing from this study to mitigate the time variation.

allocate our target sample size into each district by population. The UHIE households are clustered by residential neighbourhood, with 8–20 randomly selected households in each community. In each selected district, we randomly select communities one-by-one until the total number of households in the selected communities reaches our target size plus 10 per cent more as alternatives. In these selected communities, our enumerators surveyed all households participating in the UHIE survey to avoid the situation that households with easy access would more likely be included in our survey, while households with difficult access would be excluded.

The survey consisted of two parts and was conducted by a drop-off and pick-up approach. On the drop-off day, part 1, collecting household demographic and socio-economic information, was first completed by interviewing the primary food shopper in the household face-to-face by well-trained enumerators. Following the completion of part 1, respondents were trained on how to construct a diary record for part 2. Then, part 2 was left with the household so that the respondent could record all family members' food consumption and expenditure activities on a daily basis for one consecutive week, beginning with the drop-off day. The finished survey forms were carefully checked in the presence of the respondents and collected at the end of the survey week. Compared to the recall-based approach, the diary recording method is believed to have an advantage in generating reliable data because it lowers the likelihood of respondents forgetting food consumption activities (e.g. Ma *et al.* 2006).

Food expenditure away from home (FAFH) in our survey is defined to include almost all meals that are not prepared at home. According to this definition, FAFH includes all meals served in general restaurants, fast-food outlets, cafeterias, and small vendors or stands where consumers or those who host the meal have to pay for: (i) the ordered meals; (ii) food preparation and service; and (iii) any cost to provide dining place and environment. This definition, however, rules out all food and food products that are purchased ready-to-eat from food stores, such as supermarkets, convenience stores, and some special food stores. Instead, these types of foods are treated as fully processed foods consumed at home although they are not prepared at home.

To improve data quality, several methods were used during the survey. First, the respondent in each household was the family member most familiar with food shopping and food consumption. This selection is believed to generate more reliable data than randomly selecting a family member as the respondent. Second, in addition to a face-to-face training on how to fill out the diary forms, our enumerators also demonstrated to the respondents by recording the meals which had been consumed on the day of dropping off the diary. For example, if our enumerator went to the household in the afternoon, our enumerator recorded breakfast and lunch by asking respondents to recall what they had eaten on that day. Third, during the survey week, enumerators called the surveyed respondents at least twice to answer any questions and to provide a reminder about the diaries. Fourth, the

participation of NBS enumerators in our survey facilitated access to and cooperation from the surveyed households. Fifth, each respondent was provided with a telephone card valued at 30 yuan (or approximately \$4) so that the respondent could contact enumerators or survey leaders for any questions about the survey without incurring a cost. They could also use the cards to call those family members who ate separately from the respondents to learn what they consumed at work, school or elsewhere. Finally, the household received 100 yuan (or approximately \$15) upon completion of the survey as an incentive for diary record keeping.

## 2.2 Descriptive analysis

Meat consumed away from home accounts for a significant proportion of total meat consumption in China, both in volume and in value. Table 1 shows that per capita weekly meat consumption is 1.23 kg. Of this, 72 per cent is consumed at home and 28 per cent consumed outside of the home. Assuming there is no seasonal variation, this number means that per capita yearly meat consumption reaches 64.14 kg, including 46.4 kg at home and 17.7 kg away from home.<sup>2</sup> Pork is consistently the most important livestock protein sources for Chinese people, accounting for approximately 60 per cent of all meat in nine sampled cities. Following pork is poultry (0.23 kg/week). In terms of expenditure, per capita monthly spending on pork is more than 100 Yuan in the overall sample, which is about half of total meat expenditure. Of this, pork at home (AH) is 28 per cent, and pork away from home (AFH) is 20 per cent (Table 1).

Table 1 also shows that there is a significant proportion of households that did not consume certain meats during the survey period. For example, the uncensored observations of pork consumption at home are 96 per cent, meaning 4 per cent of the surveyed households did not consume any pork at home during the survey week. However, about 20 per cent of households did not consume pork while dining out. For beef, poultry and other meat (including mutton), the censored ratios are even higher. Given these reports

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<sup>2</sup> The household survey data conducted by the NBSC branch office in the sampled cities are not publicly accessible, which leaves us no direct means to compare our results to the official statistics. To have a rough idea about the comparison, we searched for meat consumption data in the Statistical Yearbooks at both provincial and city levels for all nine cities sampled. Unfortunately, only in five out of nine provinces involved, per capita yearly meat consumption for urban residents at provincial level is available. None of the statistics at the city level can be found. These five provinces include Shanxi, Shaanxi, Fujian, Zhejiang and Gansu. The statistics show that per capita meat consumption for urban residents in these five provinces is 27.4 kg on average in 2012, which is sharply lower than the estimated total meat consumption from our survey result (64 kg assuming no seasonal variation) and the meat at home consumption (46 kg). There are at least two possible reasons. The first one is because almost all sampled cities in our survey are the largest or second largest city in the province. It is not surprising that meat consumption is often higher in these sampled cities than other urban areas within the province. The second reason is likely related to our primary argument in this study; that is, meat consumption away from home is largely ignored by the NBSC statistics.



of zero consumption, it is important that the methodology selected for demand system estimation of meat demand in China takes these zero consumption observations into account.

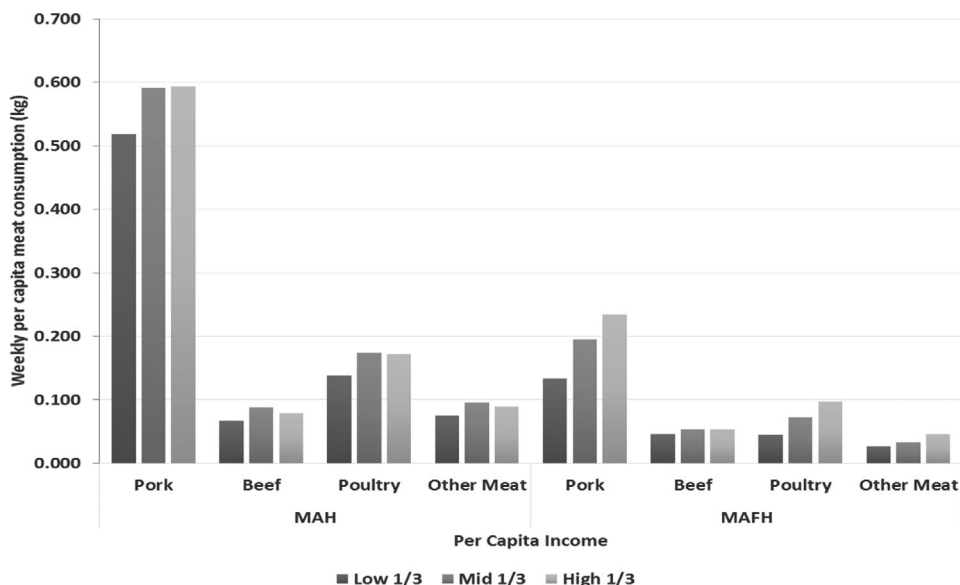
Meat consumption is apparently related to household demographic and socio-economic factors. First, meat consumption overall is increasing with income growth. However, excluding dining out meat consumption will cause a misunderstanding of the relationship between income and meat consumption. Figure 1 presents per capita meat consumption by meat variety and by three income groups (i.e. low, medium and high) for MAH and MAFH, respectively. As income rises from a low-income level, meat consumption for all meat varieties except mutton initially increases but finally peaks before declining as income increases further. On the contrary, consumption of MAFH varieties clearly shows an upwards trend as income grows. Particularly, we see a sudden jump in dining out consumption for pork, beef and poultry in the richest income group. A likely explanation for the shift is that as income rises the opportunity cost of time in preparing meat-based foods at home rises as well as the demand for leisure and food services. In summary, beyond a certain income level, rising incomes decrease consumption of MAH but encourages increased consumption of MAFH in such a way that beef, poultry and total meat consumption increase as income increases.

The literature often suggests that meat consumption or, more generally, food consumption is related to family composition (Liu *et al.* 2015). To analyse family composition effects, we first grouped the surveyed families into six types based on members' age (Table 2). Apparently, family composition matters in terms of meat consumption. For example, in our survey, we find that families consisting of only adult members consumed the highest quantity

**Table 1** Per capita weekly meat consumption (kg) and expenditure (Yuan)

	Quantity		Expenditure		% of uncensored observation
	Amount	% of total meat	Amount	% of total meat	
MAH					
Pork	0.57	46.0	13.82	35.5	96.0
Beef	0.08	6.3	3.17	8.2	39.1
Poultry	0.16	13.0	4.74	12.2	57.8
Other meat	0.09	7.0	2.68	6.9	40.1
Sub-total	0.89	72.3	24.41	62.7	NA
MAFH					
Pork	0.18	15.0	6.52	16.7	70.7
Beef	0.05	4.1	3.15	8.1	45.2
Poultry	0.07	5.7	2.81	7.2	41.1
Other meat	0.03	2.8	2.05	5.3	32.5
Sub-total	0.34	27.7	14.52	37.3	NA
Total	1.23	100.0	38.93	100.0	NA

Note: MAFH, meat consumed away from home; MAH, meat consumed at home; NA, not applicable.



**Figure 1** Weekly per capita meat consumption by income.

**Table 2** Per capita weekly meat consumption by family composition type

Family composition types	Consumption (kg)				% of MAFH			
	Pork	Beef	Poultry	Other meats	Pork	Beef	Poultry	Other meats
(1) Adult only (20–59 years)	0.799	0.147	0.245	0.149	25.50	36.60	30.10	31.20
(2) Senior only (60+ years)	0.723	0.079	0.148	0.088	10.60	25.50	6.20	9.40
(3) Adult (1) + Children (<20 years)	0.746	0.143	0.253	0.12	31.50	48.50	37.80	33.80
(4) Adult (1) + Senior (2)	0.729	0.1	0.213	0.093	15.70	24.80	21.70	22.10
(5) Senior (2) + Children	0.535	0.089	0.094	0.053	15.40	15.80	8.30	8.50
(6) Adult (1) + Senior (2) + Children	0.702	0.099	0.203	0.106	16.90	33.20	22.40	19.30

Note: MAFH, meat consumed away from home.

of meat, while families consisting of only senior and children consumed the lowest quantity of meat. As expected, other families mixed with two or three generations consumed an amount that was in between these two types of families. Also noted is that families with adult-only and adult and children consumed more MAFH than all other types of families, while for families with senior-only MAFH accounts for only 15 per cent, being at the bottom among these six types of families.

By looking across all meat varieties, we find that the presence of seniors consistently had more negative effects on family meat consumption than the presence of children did. The largest decreases in quantity consumed were for pork, beef and poultry, the three primary meats consumed in China. In



percentage terms, the effect of the presence of a senior is even more striking. Households with a senior, compared to those without, eat 30 per cent less beef, 16 per cent less poultry and 9 per cent less pork while consuming 40 per cent more other meat (including mutton and offal). It is still not clear whether people are going to eat less meat when they become elderly or if the seniors we observed in the surveys are consuming less than youths did but more than seniors consumed when they were young. If it is the former, our findings indeed suggest that the effect on meat demand is negative as the society in China is ageing, holding other effects unchanged. But if it is the latter, the effect could be positive or at least not negative.

### 3. Method

#### 3.1 Two-step approach of a censored system

Considering that income varies considerably across individual households and income elasticities differ across meat types, the Quadratic Almost Ideal Demand System (QUAIDS) developed by Banks *et al.* (1997) is utilised for analysis in this study. The QUAIDS generalises the Almost Ideal Demand System (Deaton and Muellbauer 1980) through the addition to it of a squared expenditure term. Specifically, the QUAIDS for the  $i$ th good ( $i = 1, 2, \dots, n$ ) is as follows:

$$w_i = \alpha_i + \sum_{j=1}^n \gamma_{ij} \ln p_j + \beta_i \ln \left( \frac{m}{a(\mathbf{p})} \right) + \frac{\lambda_i}{b(\mathbf{p})} \left[ \ln \left( \frac{m}{a(\mathbf{p})} \right) \right]^2 + \varepsilon_i, \quad (1)$$

where  $b = \prod_{i=1}^n p_i^{\beta_i}$ ;  $\ln a(\mathbf{p}) = \alpha_0 + \sum_{j=1}^n \alpha_j \ln p_j + \frac{1}{2} \sum_{j=1}^n \sum_{j=1}^n \gamma_{ij} \ln p_i \ln p_j$ ;  $\alpha_0, \alpha_i, \beta_i, \lambda_i, \gamma_{ij}$  are parameters to be estimated;  $w_i = p_i q_i / m$  is the budget share of good  $i$  ( $i = 1, \dots, n$ );  $n$  represents the number of goods;  $q_i$  and  $p_i$  are the quantity and price of good  $i$ , respectively;  $m$  is total expenditure; and  $\varepsilon_i$  is an error term with zero mean and constant variance. The adding-up restrictions on the parameters are  $\sum_{i=1}^n \alpha_i = 1$ ,  $\sum_{i=1}^n \beta_i = 0$ ,  $\sum_{i=1}^n \lambda_i = 0$ , and  $\sum_{j=1}^n \gamma_{ij} = 0$ . Homogeneity may be imposed by restricting  $\sum_{j=1}^n \gamma_{ij} = 0$ , and symmetry by restricting  $\gamma_{ij} = \gamma_{ji} \forall i, j$ .

The QUAIDS expenditure elasticity is equal to  $e_i = 1 + \frac{\mu_i}{w_i}$  where  $\mu_i$  is obtained from taking the derivatives of Equation (1) with respect to  $\ln M$ , that is:

$$\mu_i = \frac{\partial w_i}{\partial \ln m} = \beta_i + \frac{2\lambda_i}{b(\mathbf{p})} \left[ \ln \left( \frac{m}{a(\mathbf{p})} \right) \right]. \quad (2)$$

The Cournot (uncompensated) price elasticity is equal to  $C_{ij} = \frac{\mu_{ij}}{w_i} - \delta_{ij}$  where  $\delta_{ij}$  is the Kronecker delta, and  $\mu_{ij}$  is obtained from taking the derivatives of

Equation (1) with respect to  $\ln p_j$ , that is:

$$\mu_{ij} = \frac{\partial w_i}{\partial \ln p_j} = \gamma_{ij} - \mu_i \left( \alpha_j + \sum_k \gamma_{jk} \ln p_k \right) - \frac{\lambda_i \beta_j}{b(\mathbf{p})} \left[ \ln \left( \frac{M}{a(\mathbf{p})} \right) \right]^2. \quad (3)$$

The Slutsky (compensated) price elasticity is equal to  $S_{ij} = C_{ij} + e_i w_j = \frac{\mu_{ij}}{w_i} - \delta_{ij} + \left( 1 + \frac{\mu_i}{w_i} \right) w_j$ .

When data are complete or not censored, the QUAIDS may be estimated by iterative seemingly unrelated regressions (SUR) or maximum likelihood. However, if some households do not purchase all  $n$  goods, the problem of censoring occurs. Because the data used in this analysis were collected using household surveys, discussed previously, it is common to observe zero values in consumption for certain goods. In empirical studies, zero consumption has important econometric and economic implications, and statistical estimation procedures that do not account for these zero observations in the dependent variable can lead to biased and inconsistent parameter estimates (Amemiya 1973; Lee and Pitt 1986). To address the problem of censoring in a simple but reasonable way, Shonkwiler and Yen (1999) developed a two-step estimator.<sup>3</sup> Consider the following censored  $w_{ih}$  system<sup>4</sup>:

$$\begin{aligned} w_{ih}^* &= f(\mathbf{x}_{ih}, \boldsymbol{\beta}_i) + \varepsilon_{ih}, \quad d_{ih}^* = \mathbf{z}_{ih}' \boldsymbol{\alpha}_i + v_{ih} \\ d_{ih} &= \begin{cases} 1 & \text{if } d_{ih}^* > 0 \\ 0 & \text{if } d_{ih}^* \leq 0 \end{cases} \quad w_{ih} = d_{ih} w_{ih}^* \\ &\quad (i = 1, \dots, n, h = 1, \dots, H), \end{aligned} \quad (4)$$

where  $f(\mathbf{x}_{ih}, \boldsymbol{\beta}_i)$  is, in our case, the deterministic component of the right-hand side (RHS) of the QUAIDS, which is non-linear in  $\boldsymbol{\beta}_i$ , and the censoring of each dependent variable is governed by a separate stochastic process. For the

<sup>3</sup> In order to solve the potential bias and inconsistency of parameter estimation in censored models, researchers commonly used some sort of correction through estimation approach. Wales and Woodland (1983) first introduced the Kuhn-Tucker approach to estimate micro-level censored demand system. The Kuhn-Tucker approach derives demand (share) equations from maximising an explicitly specified random utility function after incorporating non-negativity and budget constraints. However, for some widely-used demand systems such as the AIDS and QUAIDS, it is impossible to obtain an estimable empirical form accounting for non-negativity from the utility functions (Dong and Kaiser 2003). Heien and Wessells (1990) applied a two-step estimation procedure based on the Amemiya–Tobit approach to include all observations at both steps to estimate the equation. A multivariate probit equation is estimated for each good in the demand system in the first step, and in the second step, the inverse Mills Ratio obtained from the first step is employed as an instrumented variable in a multivariable regression for each good. While this method provides unbiased and consistent parameter estimates, the estimator is not efficient (Yen *et al.* 2002).

<sup>4</sup> Shonkwiler and Yen (1999) developed their model for time-series data. Here we apply the model to household data. Accordingly, we replace the subscript  $t$  ( $= 1, \dots, T$ ), which represents time, with  $h$  ( $= 1, \dots, H$ ), which represents household.

$i^{\text{th}}$  equation and  $h^{\text{th}}$  observation, where  $i$  again represents good  $i$  and  $h$  ( $= 1, \dots, H$ ) represents household (with  $H$  representing number of households), and  $d_{ih}$  are the observed dependent variables;  $w_{ih}^*$  and  $d_{ih}^*$  are corresponding latent variables;  $\mathbf{x}_{ih}$  and  $\mathbf{z}_{ih}$  are vectors of exogenous variables;  $\boldsymbol{\beta}_i$  are vectors of parameters to be estimated; and  $\varepsilon_{ih}$  and  $v_{ih}$  are random errors, which are assumed to be jointly distributed as a bivariate normal distribution with  $\text{cov}(\varepsilon_{ih}, v_{ih}) = \tau$ . Accordingly, the unconditional mean of  $w_{ih}$  is:

$$E(w_{ih}|\mathbf{x}_{ih}, \mathbf{z}_{ih}) = \Phi(\mathbf{z}'_{ih}\boldsymbol{\alpha}_i)f(\mathbf{x}_{ih}, \boldsymbol{\beta}_i) + \delta_i\phi(\mathbf{z}'_{ih}\boldsymbol{\alpha}_i), \quad (5)$$

where  $\Phi(\mathbf{z}'_{ih}\boldsymbol{\alpha}_i)$  and  $\phi(\mathbf{z}'_{ih}\boldsymbol{\alpha}_i)$  are the univariate standard normal cumulative distribution function (CDF) and probability density function (PDF), respectively.

Using Equation (5) combined with Equation (1), the system of equations may be rewritten as:

$$w_{ih} = \Phi(\mathbf{z}'_{ih}\boldsymbol{\alpha}_i)f(\mathbf{x}_{ih}, \boldsymbol{\beta}_i) + \delta_i\phi(\mathbf{z}'_{ih}\boldsymbol{\alpha}_i) + \varsigma_{ih}, \quad (6)$$

where  $\varsigma_{ih} = w_{ih} - E(w_{ih}|\mathbf{x}_{ih}, \mathbf{z}_{ih})$ . The two-step estimation procedure uses all observations and is as follows. Firstly, estimate parameters  $\boldsymbol{\alpha}_i$  with probit using maximum likelihood to obtain  $\hat{\alpha}_i$ . Next, calculate  $\Phi(\mathbf{z}'_{ih}\hat{\alpha}_i)$  and  $\phi(\mathbf{z}'_{ih}\hat{\alpha}_i)$  and use iterative feasible non-linear SUR in the second step to estimate  $\boldsymbol{\beta}_1, \boldsymbol{\beta}_2, \dots, \boldsymbol{\beta}_n$  and  $\delta_1, \delta_2, \dots, \delta_n$  in the system:

$$w_{ih} = \Phi(\mathbf{z}'_{ih}\hat{\alpha}_i)f(\mathbf{x}_{ih}, \boldsymbol{\beta}_i) + \delta_i\phi(\mathbf{z}'_{ih}\hat{\alpha}_i) + \varsigma_{ih}, \quad (7)$$

with maximum likelihood.

### 3.2 Estimation procedure and price

In demand systems, the corresponding covariance matrices are generally singular, and QUAIDS is no exception. The singularity is due to adding-up restrictions that are automatically maintained. Adding-up is simply that, summing over all  $n$  equations, the sum of the left-hand side, in the case of QUADS equals to one, is exactly equal to the sum of the right-hand side. Barten (1968) proves that demand systems with singular covariance matrices can be estimated by dropping one equation, say the  $n^{\text{th}}$ , and estimating the remaining  $n - 1$  equations together. He shows that the parameters of the system are invariant as to which equation is dropped, and the parameters of the  $n^{\text{th}}$  equation may be recovered through the adding-up restrictions. However, when accounting for zero consumption of some goods by some households, the resulting demand system in the second step of the Shonkwiler–Yen method violates adding-up, that is, when multiplying the right-hand side of each of the QUAIDS equations by the corresponding CDF and adding a corresponding PDF, the sum of the left-hand side over all  $n$

equations is no longer equal to that of the right-hand side over all  $n$  equations.<sup>5</sup> Still, in practice, researchers have estimated the second-step system by dropping one equation and arguing that the violation of adding up does not affect the parameters of the system too much (e.g. Coelho *et al.* 2010). However, the implication of violating adding up is that the parameters of the system are no longer invariant as to which equation is dropped for estimation purposes. Thus, it is not possible to recover the parameters of the dropped equation exactly through adding up.

In this paper, we take advantage of violating adding up in the second stage by noting that the system's covariance matrix is no longer singular. As such, in principle, one can estimate Equation (7) using all  $n$  equations (Yen *et al.* 2002; Ecker and Qaim 2010). Accordingly, the resulting parameters are not invariant to which equation is dropped, and one can estimate the complete system without dropping an equation. The parameters, of course, are variant to restrictions imposed and to the addition of any socio-economic variables that may be added to Equation (7) as control variables. In what follows, the resulting parameter and elasticity estimates are based on estimating the first-step equations with probit, calculating the CDF and PDF for each equation, and lastly estimating Equation (7) as a complete  $n$ -equation system with maximum likelihood using iterative feasible non-linear SUR.

The price of specific meat in our model is the adjusted expenditure price. During the survey, the sampled households were asked to record the names of all dishes (describe dish ingredients if known), price of each dish and the total expenditure of each meal for any eating out consumption and processed dishes at home. The purpose was to mitigate the household burden for participating in the survey and to overcome the impossibilities for the diners to decompose dishes into ingredients. To obtain the expenditure and price information for meat, particularly for MAFH and in processed form, we converted the observed dish expenditure and dish price into prices for specific meats. We use a three-step procedure to do so. First, we employed a dish-to-ingredient matrix which consists of nearly 10,000 dish recipes to convert all observed dishes into ingredients. Then, prices for specific meats consumed away from home or in processed form at home were then generated based on the ingredient share, in quantity in each dish, the observed dish price, the average price for fresh meat in each city (calculated by taking average of the observed purchases in our survey) and outlet category serving the dish (including restaurants, fast-food outlets and cafeteria). Last, the generated prices for specific meat dishes were summed-up and averaged for each sample household. By this procedure, the generated price for a specific meat is not only related to the expenditure

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<sup>5</sup> Other methods such as the Heien and Wessells (1990) and Heckman (1979) methods that account for zero consumption of some goods by some households also lead to the violation of adding up in the demand system being estimated.

price paid for the dish, but also related to the ingredient share in each dish, the average price of meat in each city and the outlet category. Theoretically, this procedure cannot completely remove price endogeneity concerns but mitigates it to an acceptable level.

#### 4. Empirical results

A main purpose of the probit estimation in the first step of the Shonkwiler–Yen method is to calculate a PDF and CDF for each of the eight meat types to be used for estimation purposes in step 2, the QUAIDS estimation. The probit estimations also provide information on whether included exogenous variables increase or decrease the probability of participating in the consumption of each of the eight meat types. Following Liu *et al.* (2015), who find that household composition variables of age structure are important in explaining demand for aggregate food away from home in China, seven household age composition variables are included. The seven household composition variables are the number of household members in the age groups: <9; 10–19; 20–29; 30–39; 40–49; 50–59; and >60. Additionally, we include health indicator variables. The health indicator variables indicate whether a household member has certain ailments such as high cholesterol level or high blood sugar level that might affect participation in consumption of some of the meats. In the second step, only seven household age composition variables are controlled given the sample limitation. Finally, total meat expenditure is included as one of the exogenous variables.

Two findings stand out for all meats: the likelihood of participation in consumption of all eight meat types increases as per capita total meat expenditure increases, and there is a negative relationship between the own price of a meat and participation in consumption of that meat. This indicates that the higher own price is for a meat type, the less likely is participation by the household in purchasing that meat type.

##### 4.1 Conditional expenditure elasticities for four meat types, AH and AFH

Based on estimated parameters in both stages, step 1 (probit) and step 2 (QUAIDS), we calculate conditional expenditure elasticities for the eight meat types, four AH and four AFH. Specifically, expenditure elasticities are dependent upon both the probit (step 1) estimation and the QUAIDS estimation (step 2) when steps one and two contain some of the same explanatory variables. These elasticities are conditional on total meat expenditure,  $m_M$ , and measure the per cent change in quantity demanded of good  $i$  when total meat expenditure changes by 1 per cent.

First, rewrite Equation (7) leaving off the  $h$  subscript for convenience as  $w_i = \Phi(\mathbf{z}'_i \boldsymbol{\alpha}_i) w_i^* + \delta_i \phi(\mathbf{z}'_i \boldsymbol{\alpha}_i)$  where

$$w_i^* = f(\mathbf{x}_i, \boldsymbol{\beta}_i) = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln \frac{m_M}{a(\mathbf{p})} + \frac{\lambda_i}{b(\mathbf{p})} \left[ \ln \left( \frac{m_M}{a(\mathbf{p})} \right) \right]^2, \quad (8)$$

is the determinant RHS of the conditional QUAIDS. To calculate conditional expenditure elasticities for the eight meat types, we first derive the marginal effects as follows:

$$\begin{aligned} \mu_i^* &= \frac{\partial w_i}{\partial \ln m_M} = \frac{\partial \Phi}{\partial \ln m_M} w_i^* + \Phi \frac{\partial w_i^*}{\partial \ln m_M} + \delta_i \frac{\partial \phi}{\partial \ln m_M} \\ &= \phi c_i w_i^* + \Phi \left[ \beta_i + 2 \frac{\lambda_i}{b(\mathbf{p})} \ln \frac{m_M}{a(\mathbf{p})} \right] + \delta_i \phi (-\mathbf{z}'_i \boldsymbol{\alpha}_i) c_i, \end{aligned} \quad (9)$$

where  $c_i$  denotes the estimated parameter of  $\ln m_M$  in the 1st step, and  $\Phi(\mathbf{z}'_{ih} \boldsymbol{\alpha}_i)$  and  $\phi(\mathbf{z}'_{ih} \boldsymbol{\alpha}_i)$  are simply represented as  $\Phi$  and  $\phi$ . This marginal effects formula differs from that of Yen *et al.* (2002) and of Ecker and Qaim (2010). The former estimated a translog demand system in the second step, and none of the variables in the first or second steps was the same. As such, total group expenditure was not included in step 1, and the CDFs and PDFs from step 1 were not functions of total group expenditure. Ecker and Qaim did include total group expenditure, total food expenditure in their case, in steps one and two, but their derivation followed that of Yen *et al.* As such, Ecker and Qaim did not take into account that  $\Phi$  and  $\phi$  were functions of total group expenditure.

Having obtained the  $\mu_i^*$ , the formula for calculating the conditional expenditure elasticity of the conditional QUAIDS is  $e_i^C = 1 + \frac{\mu_i^*}{w_i^*}$ . These conditional expenditure elasticities and their associated asymptotic confidence intervals are calculated using the Delta method with 1,000 iterations, calculated at the sample mean, and are reported in column (3) of Table 3 for the four meat groups consumed at home and for the four consumed away from home. All conditional meat expenditure elasticities are positive and significantly different from zero as indicated by the 95 per cent confidence level also obtained from the Delta method. All are different from unity with the conditional expenditure elasticity of pork AH (0.66) statistically less than unity, indicating that, if total expenditure on meat increases, the quantity demanded for pork AH will increase at a slower rate. All other conditional expenditure elasticities are statistically greater than unity indicating that, if total expenditure on meat increases, the quantity demanded for these meat types will increase at a faster rate. What is noticeable is that the conditional elasticities of the four meat types of AH are less elastic than the corresponding ones for meat types of AFH. This suggests that, as total meat expenditure increases in response to growth in income, the quantities of meat types of AFH will increase faster than meat types of AH. For both AH and AFH, the expenditure elasticity of beef is relatively high, suggesting beef



Table 3 Expenditure and own-price elasticities for meat consumed at home and away from home, urban China

Commodity	Expenditure elasticity			Own-price elasticity		
			95% Conf. level	Slutsky		Cournot
	Unconditional	Conditional		Conditional	95% Conf. level	
	(1)	(2)	(3)	(4)	(5)	(7)
MAH						
Pork	0.27	0.66	0.64	0.68	0.94	-0.60
Beef	0.64	1.50	1.32	1.68	-1.40	-1.30
Chicken	0.61	1.49	1.40	1.61	-1.07	-0.91
Other meat	0.56	1.36	1.18	1.57	-1.14	-1.06
MAFH						
Pork	0.49	1.18	1.11	1.26	-0.85	-0.69
Beef	0.76	1.85	1.65	2.03	-1.99	-1.89
Chicken	0.70	1.71	1.46	1.91	-1.98	-1.92
Other meat	0.86	2.11	1.77	2.53	-2.05	-1.99

Note: MAFH, meat consumed away from home; MAH, meat consumed at home.

quantity in both cases will increase at a faster rate than other meat types with the only exception of other meat AFH.

These conditional expenditure elasticities have important marketing implications. With China's rapid economic growth, household disposable income has also significantly increased over the last three decades, and real income is expected to continue to grow with a remarkably high growth rate. As a result, household expenditures for meat consumption are expected to increase as well. Our estimated conditional expenditure elasticities suggest that the most substantial increase will happen for MAFH rather than MAH. Meanwhile, except for pork AH, all other meat types will increase more rapidly than the increase in total expenditure on meat.

#### 4.2 Unconditional expenditure elasticities for food, meat and meat types

Expenditure elasticities conditional on total meat expenditure measure the per cent change in the quantity of meat type  $i$  for a 1 per cent change in total meat expenditure. While this provides important information concerning meat consumption patterns, one often prefers an unconditional expenditure elasticity that measures the per cent change in quantity demanded of meat type  $i$  with respect to a 1 per cent change in total expenditure (i.e. the sum of total expenditures on food, clothing, transportation, communication, education and all other aggregate goods in the market). One also often prefers unconditional expenditure elasticities for simulations of future consumption patterns from scenarios of growth of income (expenditures) into the future. To obtain these, we make use of multistage budgeting where the consumer allocates her total expenditure in stages (Barten 1977). In the first stage, the household allocates total expenditure on all goods among aggregate goods such as food, clothing and transportation. Next, based on total group expenditures such as total food expenditure, the household further allocates that food expenditure among categories of food such as meats, vegetables and fruits,, and then in the third stage, for example, the household allocates total meat expenditure among types of meat, including AH and AFH. To turn our conditional meat-type expenditure elasticities into unconditional ones, we need the expenditure elasticity of the meat group conditional on total food expenditure as well as the expenditure elasticity of food conditional on total expenditure for all goods. The latter elasticity is called the unconditional income elasticity of demand for food.

To calculate the unconditional income elasticities for food, we fit Working's (1943) model to the food budget share,  $W_F$ , and total income data,  $m$ , collected in the nine Chinese cities, that is:

$$W_F = \alpha_F + \beta_F \ln m + \varepsilon_F, \quad (10)$$

where the F subscript represents food. The unconditional income elasticity of food in this model is equal to  $E_F^U = 1 + \frac{\beta_F}{\hat{W}_F}$  where  $\hat{W}_F = \hat{\alpha}_F + \hat{\beta}_F \ln m$ .

Working's model fit to meat consumption is  $W_M = \alpha_M + \beta_M \ln m_F + \varepsilon_M$  where the  $M$  subscript represents meats. The conditional expenditure elasticity of meat is  $E_M^C = 1 + \frac{\beta_M}{\hat{W}_M}$  where  $\hat{W}_M = \hat{\alpha}_M + \hat{\beta}_M \ln m_F$ . The unconditional expenditure elasticity of meat is the product of the unconditional expenditure elasticity of food times the conditional expenditure elasticity of meat,  $E_M^U = (E_F^U)(E_M^C)$ . The unconditional expenditure elasticity for each meat type  $i$  is equal to the product of the two expenditure elasticities above times the conditional expenditure elasticity of meat  $i$ ,  $e_i^U = (E_F^U)(E_M^C)(e_i^C)$ .

The unconditional income elasticity for food is estimated to be 0.38 at the sample mean, and the conditional expenditure elasticity of meat at the sample mean is 1.10, with the unconditional expenditure elasticity of the meat group equal to 0.41. Using these estimates and the formula above, we calculate unconditional expenditure elasticities for the eight meat types and report them in column (2) of Table 3.

All unconditional meat expenditure elasticities are positive but less than unity indicating they are all necessities. These elasticities range from 0.27 for pork AH to 0.86 for other meats AFH. Pork has the lowest expenditure elasticity in both the MAH and MAFH groups, but its AH expenditure elasticity is just over half the size of its AFH expenditure elasticity. The unconditional expenditure elasticity for beef AH and poultry AH is essentially the same, but beef AFH is more elastic than poultry AFH.

The significantly positive expenditure elasticities also have important implications for domestic agricultural production and international trade, especially for feed grain such as corn and soya bean meal. China's livestock production has grown rapidly in response to higher consumer demand. Our estimated elasticities indicate that the rapidly increasing demand for meat will continue to bring pressure on China's domestic meat production. Despite China's ability to achieve a relative high self-sufficiency rate for most agricultural commodities so far, a big question is whether China will continue to be successful and stay in a comfortable position to meet the challenges from the rapidly shifting diet, from one centred on staple foods to one incorporated with more livestock protein such as meat. Our findings from this study suggest that the challenge could be more severe than what most people expected if we take meat consumption away from home into consideration.

### 4.3 Conditional own-price elasticities

Like the conditional expenditure elasticities, Slutsky and Cournot own-price elasticities conditional on total meat expenditure are calculated taking into account both first- and second-step parameters because several explanatory variables are included in both the probit equations and the QUAIDS. The conditional Slutsky price elasticities are compensated in that real total meat expenditure is held constant after a price change, while conditional Cournot price elasticities keep nominal total meat expenditure constant and thus include both price substitution effects and income effects of a price change.

To calculate the price elasticities, we first derive the marginal effects as follows:<sup>6</sup>

$$\begin{aligned} \mu_{ij} = \frac{\partial w_i}{\partial \ln p_j} &= \frac{\partial \Phi}{\partial \ln p_j} \cdot w_i^* + \Phi \cdot \frac{\partial w_i^*}{\partial \ln p_j} + \delta_i \frac{\partial \phi}{\partial \ln p_j} = \phi \cdot \xi_i \cdot w_i^* \\ &+ \Phi \cdot \left[ \gamma_{ij} - \left( \beta_i + 2 \frac{\lambda_i}{b(\mathbf{p})} \cdot \ln \frac{m}{a(\mathbf{p})} \right) \cdot \left( \alpha_j + \sum_i \gamma_{ij} \ln p_i \right) \right. \\ &\left. - \frac{\lambda_i \beta_i}{b(\mathbf{p})} \left[ \ln \left( \frac{m}{a(\mathbf{p})} \right) \right]^2 \right] + \delta_i \cdot \phi \cdot \left( -z'_i \alpha_i \right) \cdot \xi_i, \end{aligned} \quad (11)$$

where  $\xi_i$  is the estimated parameter for  $\ln p_j$  in the  $i^{\text{th}}$  equation in the 1<sup>st</sup> step. The Cournot (uncompensated) price elasticity can be expressed as:

$$C_{ij}^u = \frac{\mu_{ij}}{w_i} - \delta_{ij}, \quad (12)$$

where  $\delta_{ij}$  is the Kronecker delta. By the Slutsky equation, the Slutsky (compensated) price elasticity can further be derived as:

$$S_{ij}^C = C_{ij}^C + e_i^C w_j^*. \quad (13)$$

These conditional Slutsky and Cournot own-price elasticities and their associated asymptotic confidence intervals are calculated using the Delta method with 1,000 iterations, calculated at the sample mean, and are reported in columns (5) and (7), respectively, of Table 3 for the four meat types of AH and the four meat types of AFH. All conditional own-price elasticities are negative and significantly different from zero as indicated by the 95 per cent confidence level also obtained from the Delta method.

In terms of the conditional Slutsky own-price parameters, only that of pork AH is statistically greater than negative one. Both pork AFH and chicken AH have Slutsky own-price elasticities being statistically the same as negative one. All other meat types have Slutsky own-price elasticities that are statistically smaller than negative one, suggesting these are all price elastic during the study period. As expected, all conditional Slutsky own-price elasticities of the meat types of AH are statistically larger (less negative) than the corresponding meat types of AFH, indicating that meat types of AFH are more responsive to own-price changes than are corresponding meat types of AH. In terms of the Cournot own-price

<sup>6</sup> As with the marginal effects used for calculating expenditure elasticities, this formula differs from Yen *et al.* (2002), because they had no explanatory variables in both steps one and two, and from Ecker and Qaim (2010), because they followed the derivations of Yen *et al.* (2002) and did not account for effects through the CDF and PDF for variables in both steps.

elasticities, they are all statistically less negative than the Slutsky counterparts.

### 5. Conclusions and implications discussion

With a rapidly shifting diet in urban China driven by dramatic economic growth and urbanisation, analysing meat demand in the country has important implications for understanding domestic food market and international trade for agricultural commodities. In this study, we jointly consider meat consumed at home and away from home by using our own survey data from nine cities. We investigate the role of including meat away from home in obtaining a comprehensive understanding of meat demand in China.

We find that urban household expenditure elasticities on meat away from home are consistently higher than those eaten at home. This finding not only suggests that meat consumption away from home could increase more than proportionately to total meat expenditure, but also indicates that excluding MAFH could mislead one's understanding of the meat consumption trend in China and its implications for domestic supply and international trade.

We also found that expenditure elasticities vary across meat categories, but all are significantly positive. This result suggests that income is still a critical force driving meat demand to increase. Further, the findings suggest that the consumption of beef and poultry will grow at a relatively higher rate than pork consumption.

Regarding price effects, we found that dining out for meat consumption is more responsive to price than is meat purchased for home consumption. Within meat consumption at home, however, we found that beef and other meat are substitutes for pork, while poultry is a complement for pork. Differently, meats consumed away from home are complements to each other. One reasonable explanation is when the price of one type of meat increases, Chinese urban households will simply cut down their frequency of dining out rather than shifting to other meats when they eat out.

The findings of this study have critical implications. For meat and feed industries, the central concern is apparently how big the market in China will be for their products and how fast the market is emerging. For policymakers, the top concern is how to meet the increasing meat demand and, at the same time, to reach China's sustainable agricultural development plan, which is more environment-friendly compared with the past agricultural production system. As animal production, particularly for meat, is generally more land, water and energy intensive than that of grain and vegetables (Jiang *et al.* 2015), the continuously increasing meat demand in China will generate more pressure on the production side. Moreover, as meat and dairy production often play a big role in increasing greenhouse gas emission (Hawkins *et al.* 2018), the result from this study indicates that China's development goal in controlling GHG emission will face an increasing challenge due to

continuously increasing meat consumption. Therefore, Chinese government must face a difficult choice between a high self-sufficiency rate for meat and its goal in developing a sustainable agricultural system.

So, how to meet these goals that are conflicting with each other? The first policy tool for China's government is to rely more on the international market for meat or animal feed to reduce domestic pressure in meeting the high self-sufficiency goals. Another possible policy choice is to promote the Chinese dietary guidelines. A recently published article in *The Lancet* shows that China has passed the USA to become the frontrunner in the absolute number of obese citizens (NCD-RisC 2016), which reflects a sharp increase from the beginning of the reform and opening in the late 1970s. A study recently published demonstrates that reducing meat, egg consumption and increasing fruit, vegetables and dairy consumption by guiding consumer's dietary structure could improve both diet quality and environmental sustainability (Lei and Shimokawa 2017). A study by He *et al.* (2019), however, indicates that the GHG emissions, water consumption and land occupation would all increase if Chinese consumers follow healthy diets as recommended by the 2016 Chinese Dietary Guidelines rather than their current diets. Thus, whether promoting dietary guidelines to curb the rising obesity problem could also benefit the environment and agricultural sustainable development remains unclear. How to guide consumer's preferences and food choices is a major challenge, which suggests the need for more policy tool innovations.

### Data availability statement

Research data are not shared. We expect to make it publicly available in 2 years.

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