# The Effect of Refrigerator Use on Meat Consumption in Rural China

**Jing Zhao**
Department of Agricultural and Applied Economics
University of Missouri
324 Mumford Hall, Columbia, MO, 65211
Phone: (573) 355-7991
Email: jzm95@mail.missouri.edu

**Wyatt Thompson**
Department of Agricultural and Applied Economics
University of Missouri
Food and Agricultural Policy Research Institute at the University of Missouri
101 Park DeVille Drive, Suite E
Columbia, MO 65203
Phone: (573) 882-1864
FAX: (573) 884-4688
Email: ThompsonW@missouri.edu

***Selected Paper prepared for presentation at the Southern Agricultural Economics Association (SAEA) Annual Meeting, Orlando, Florida, 3-5 February 2013***

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**Abstract:** Refrigerator ownership in rural China increased from 14% to 45% over the period 2001-2010.We test the impact on demand for food, particularly meat, using fixed-effect and demand system approaches based on provincial data. Results suggest that rising refrigerator ownership had a negative effect on rural at-home meat demand.

**Key words:** refrigerator, meat demand, rural China

**JEL classification codes:** Q11, Q18

## Introduction

With income growth and technological progress, home infrastructure has been increasing quickly in developed countries (Bowden and Offer, 1994), as well as in developing countries (McNeil and Letschert, 2005). Refrigerator, as one of the key kitchen appliances, is expected to have an important effect in extending food life and improving people's standard of living. Owning refrigerators allows consumers to reduce their frequencies of food purchasing from wet markets, and also encourages them to diversify their food purchase according to their preferences (Lyon and Durham, 1999).

In China, the government subsidized home appliance purchases by rural consumers. The level of the subsidy is currently 13% of the home appliances price. Since Dec 1, 2007, refrigerators, as well as televisions and mobile phones, were subsidized in Shandong, Henan and Sichuan Provinces. This policy was extended to 14 provinces since Dec 1, 2008, and launched countrywide on Feb 1, 2009. Thus, the adoption of refrigerators in rural China has sharply increased, and the national average number of refrigerator owned by per 100 households in rural China rose from 13.6 in 2000 to 45.2 in 2010 (Chinese Statistical Yearbook, 2002 and 2011). In sharp contrast, 42.33% of urban households owned refrigerator in 1990, which suggests that the diffusion of refrigerators in rural China lags the pace in urban areas by 20 years (Chinese Statistical Yearbook, 2011).

The question we are addressing here is how refrigerator ownership has affected food demand in China, with a specific focus on meat consumption. After rural residents of China own refrigerators, they may shift their food demand from nonperishable goods, like grains, to perishable goods, such as meat, seafood, vegetables, etc. If this is the case, then the transition from a low refrigerator ownership rate to a high ownership rate would be associated with a one-

time shift in demand patterns. Researchers who ignore this effect might attribute shifts in demand to other factors, such as rising rural income or changing preferences. If the former factor is believed to explain more of the recent rural demand changes because the refrigerator effect is ignored, then rural income elasticities might be biased. If the refrigerator ownership does matter, we can make better prediction of rural food consumption in the long run by taking this factor into account, which is essential for policy makers to evaluate the supply and demand of grain.

The implications are speculative until empirical tests of our hypothesis are complete. To address the problem, we review the literature on the topic, summarize relevant data, and present two methods to test the impact of refrigerators on at-home food demand in rural China. Cutting to the chase, results reported here do not support our initial hypothesis that expanding refrigerator ownership in rural China led to greater at-home meat consumption. On the contrary, test results generally go in the opposite direction, suggesting that greater refrigerator ownership might cause lower at-home meat consumption in rural areas. We end the assessment by discussing these results, including a restatement of the limits to our approach and some possible reasons why this result might be observed.

## Literature Review

Food consumption in China has been the focus of many scholars and policy makers. Many scholars have found that China has great potentials for meat demand as income increases, and will reduce the direct grains consumption. Hsu et al. (2002) also proposed that high income people will consume more meat, fruits, dairy products, aquatic products, and less rice and grain compared to low income population. In addition, seniors consume more rice, fruits and vegetables, instead of meat, beer. Ortega et al. (2009) analyzed meat demand using a linear approximation of an almost ideal demand system. Their results show that pork as the primary meat in China has become a necessity while the other meats are still luxuries, and predicted that the large share of meat expenditure increase in the future will be allocated to pork.

In urban China, meat consumption has shown the rise trend with income growth. For instance, Yen et al. (2004) investigated household food consumption in urban China using a translog demand system and found that milk and most meat products are not only more price responsive than demand for other food and but also have high expenditure elasticities. Zheng and Henneberry (2009) evaluated the economic and demographic effects on food consumption for grains, meats, poultry, aquatic products, dairy products, vegetables, and fruits, based on urban household data from Jiangsu Province utilizing an almost ideal demand system (AIDS) model. Their results indicated that the demand for foods of animal origins, such as meats, poultry, aquatic products, and dairy products, will increase by a larger magnitude compared to other foods with expenditure growth and they also find that demographic factors have a significant effect on food consumption. In addition, Zheng and Henneberry (2010) found that wheat flour and coarse grains are price elastic, while rice and grain products are price inelastic, and

demographic factors matters in food consumption. Moreover, they argue, China may allocate more land to feed grains with the decrease of rice demand. With the rising income after the reforms towards market-orientation in China, the demand for food away from home has been increasing sharply, paralleling by rapidly rising meat consumption, which can explain part of the apparent food stagnation in the late 1990s and potentially accounted for some of the inconsistency between China's livestock production and meat consumption data (Ma, Huang, Fuller, Rozelle, 2006). Bai et al. (2012) extend at-home food use data by resurveying selected urban respondents and developing away-from-home food consumption. Estimating a quadratic almost idea demand system (QUAIDS) over these data lead these authors to suggest that much higher expenditure effects on meat consumption away from home than at home for urban consumers.

A large part of the literature investigated the influencing factors and elasticities of the rural food consumption based on rural data in China. Halbrendt et al. (1994) analyzed consumer behavior based on the rural Guangdong Household survey data. Their results indicated that most food commodities are not price elastic, and the substitution effect due to relative price changes are small, except for grains. However, in their results, meats, poultry, fruits, sweets, and durable goods are sensitive to expenditure change. Gao et al. (1996) estimated the effects of economic and demographic factors on China's rural household demand for nine food commodities in a two-stage demand system that combined an upper level AIDS and a lower-level generalized linear expenditure system as a modeling framework. Their results show that slow rural demand growth for food in the latter half of 1980s resulted from income stagnation rather than consumption saturation, and demand for high quality food and shelter would be priorities in the event of future the income increases. As income grows, consumers in rural China will consumption more high quality foods and more expensive foods, such as meats and dairy products (Yu and Abler, 2009).

Some studies find that convenience and access to a market were also important factors determining meat consumption. For example, market development in rural China was incomplete at the time of many studies, and might still be in some areas, and this context might affect the demand for foodstuffs, in particular meat (Huang and Rozelle, 1998). However, as economy develops, supermarkets tend to replace central food markets, neighborhood stores, and street sellers of food in urban areas (Pingali, 2006). Peng et al. (2005) conducted a survey in Shanghai and Nanjing for the livestock consumption and found that supermarkets and food store chains are the most important retail outlets for frozen/chilled livestock products, especially in large and mid-size cities.

From the above review, we conclude that the bulk of the literature studying food demand in China focuses on economic factors, like price and income, and a selection of demographic factors, such as household size, education level, and location. However, the effects of refrigerator ownership on food consumption are not widely studied, and the studies we have identified do not

focus on meat demand in rural areas. Lyon and Durham (1999) included refrigerator ownership, but they used urban data rather than rural data for the following reasons that they argued in the article. First, urban data is more extensive. Second, refrigerators have more important influence on urban food consumption because consumers are far away from the agricultural markets. In addition, price data were extrapolated from price indices. The authors constructed food quantity models and food expenditure models. The food quantity demand model includes food prices, food at home expenditures, dining out expenditure, refrigerator ownership, and dummies for regions as explanatory variables. Own price coefficient in all these models were negative and significant at the 5% level. The refrigerator ownership was estimated to have positive and significant effects on the quantity of meat and eggs consumed, and statistically negative for grains. Expenditure models tested the effects of refrigerator ownership, income, and own price. Refrigerator ownership contributed to egg and milk expenditure increase, the authors find, and caused grain expenditure to decrease significantly. However, the authors found that refrigerator ownership had no significant effect for meat expenditure

Gale et al. (2005) used Working-leser model, arguing that this is model is relatively easy to estimate and has desirable properties that are reflected in households' budget share of each food group in rural China. The dependent variable is the share of expenditure, and the explanatory variables include per capita total expenditure and household characteristics, such as refrigerator owned, migrants working outside of the hometown, size of household, cultivated land area, family plot size, children under age 6, children age 6-15, and persons with senior high school education or higher. The model used household data from Heilongjiang, Henan, and Jiangsu Provinces for 1995 and 2001, which covers over 9,000 households in the three provinces each year. Six equations were used for cash food, noncash food, and nonfood expenditure share. The results show that refrigerator ownership has positive effect on cash food expenditure share. Among cash food expenditure categories, refrigerator ownership has positive effect on vegetables, meat and eggs, fish, other foods, and tobacco/alcohol, while it affects the budget share of grains and food away from home negatively. Based on the results, the author argued that households that own refrigerators tend to allocate more of their budgets to cash food and less to noncash food expenditure, and spend more on perishable food. The drawback of the model is that they did not include any price data. Even though they argue that price effect on food consumption in rural China is complicated because rural farmers in China are both producers and consumers, ideally prices would be included for an analysis of demand. More generally, if the agricultural products market is complete, all products can in principle be exchanged into income.

Given that previous research suggests an important effect of refrigerator ownership on consumer purchasing behaviors, and more specifically on meat demand, incorporating refrigerator use into demand analysis is essential and vital for us to understand the China food market in the long run. In this research, our goal is to characterize the effect of refrigerator ownership on rural food consumption at home. To achieve this goal, the objective is to test whether the refrigerator use can change food consumption pattern of rural people. In the next section, we summarize the data

we use and apply two methods to test the impact of refrigerators on at home food consumption in China.

## Data and Method

### (1) Data

This research uses panel data consisting of provincial level data for ten years, 2001 through 2010. Data are from the China Statistical Yearbook and China's Yearbook of Rural Household Survey, published by China National Statistics Bureau, as well as Yu and Abler (2009). The consumption data of each food group, the percentage of refrigerator ownership, and the per capita income are all from the China Statistical Yearbook. The price data in 2001 are from Yu and Abler (2009). Combining the food price in 2001, the price data in other years were computed based on the provincial level consumer price index (CPI) for each food group. All nominal income data were converted into real values using rural China CPI based on the year 2001.

**Table 1 Statistics Summary of refrigerator ownership and major outcome variables**

| Year | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 |
|---|---|---|---|---|---|---|---|---|---|---|
| Refrigerator Ownerships | | | | | | | | | | |
| Mean | 11.0 | 12.1 | 13.1 | 14.9 | 18.9 | 22.5 | 27.3 | 30.8 | 37.6 | 45.2 |
| Medium | 7.4 | 8.7 | 8.9 | 10.6 | 14.4 | 18.4 | 24.8 | 29.3 | 37.0 | 45.4 |
| Std. Dev | 9.6 | 10.0 | 10.9 | 11.8 | 13.3 | 15.1 | 16.3 | 16.4 | 17.3 | 17.8 |
| Min | 2.9 | 3.5 | 3.4 | 3.9 | 6.7 | 7.2 | 8.4 | 8.6 | 11.3 | 15.0 |
| Max | 46.6 | 48.6 | 53.1 | 56.6 | 66.5 | 71.4 | 78.3 | 83.4 | 88.9 | 92.3 |
| Grain consumption per capita (Kg) | | | | | | | | | | |
| Mean | 239.1 | 238.6 | 222.5 | 218.4 | 209.5 | 206.6 | 200.2 | 199.2 | 188.9 | 181.9 |
| Medium | 236.1 | 233.4 | 224.0 | 218.0 | 207.3 | 204.0 | 197.0 | 192.2 | 187.0 | 177.6 |
| Std. Dev | 21.0 | 27.6 | 20.3 | 19.0 | 22.0 | 20.7 | 20.3 | 22.1 | 20.1 | 21.9 |
| Min | 205.4 | 201.6 | 193.3 | 189.7 | 175.0 | 166.9 | 159.1 | 166.4 | 153.3 | 142.9 |
| Max | 283.2 | 335.5 | 264.8 | 264.2 | 261.6 | 260.2 | 255.0 | 246.1 | 232.2 | 235.9 |
| Meat consumption per capita (Kg) | | | | | | | | | | |
| Mean | 17.0 | 17.6 | 18.5 | 17.8 | 20.3 | 20.5 | 18.7 | 18.3 | 19.6 | 19.9 |
| Medium | 15.9 | 16.6 | 17.8 | 17.6 | 19.8 | 20.3 | 18.4 | 18.9 | 19.6 | 19.4 |
| Std. Dev | 7.1 | 7.0 | 8.2 | 7.8 | 8.3 | 8.5 | 8.0 | 7.8 | 8.3 | 8.0 |
| Min | 4.7 | 5.5 | 5.6 | 5.9 | 6.0 | 6.8 | 6.1 | 5.8 | 6.4 | 7.6 |
| Max | 31.2 | 30.5 | 32.7 | 32.9 | 36.0 | 35.3 | 32.7 | 32.8 | 33.8 | 34.3 |

From 2001 to 2010, the average ownership rate of refrigerator among rural household increased from 11% to 45.2% (seen in Table 1). Meanwhile, average grain consumption decreased from 239.1 kg per capita in 2001 to 181.9 kg per capita in 2010. Meat consumption rose from 17 kg per person in 2001 to 19.9 kg per person in 2010.

**(2) Method**

**a. Demand equation**

The causal relationships will be estimated using the following regressions. A fixed effect model is employed to analyze the effect of refrigerator ownership on rural food consumption. According to demand theory, the consumption of each food group is a function of its own price, substitute prices, income, and household characteristics such as household size, the number of household labor, the average education level, house size, arable land size. Assuming that food consumptions are heterogeneous among different provinces, we pick out the percentage of refrigerator ownership. The rest of heterogeneity among areas was explained by province fixed effect.

The estimated equations take the following form:

$$Q_{ijt} = \alpha + \beta_1 GRAINP_{jt} + \beta_2 FATOILP_{jt} + \beta_3 MEATP_{jt} + \beta_4 EGGP_{jt} + \beta_5 SEAFOODP_{jt} + \beta_6 VEGEP_{jt} + \beta_2 FRUITP_{jt} + \delta Ln(RINC_{jt}) + \varphi REFRI + \gamma_1 HHS_{jt} + \gamma_2 HHL_{jt} + \gamma_3 HS_{jt} + \gamma_4 EDUC_{jt} + \gamma_5 STUD_{jt} + e_{ijt} \quad (\mathbf{1})$$

and

$$Q_{ijt} = \alpha + \beta_1 GRAINP_{jt} + \beta_2 FATOILP_{jt} + \beta_3 MEATP_{jt} + \beta_4 EGGP_{jt} + \beta_5 SEAFOODP_{jt} + \beta_6 VEGEP_{jt} + \beta_2 FRUITP_{jt} + \delta_1 Ln(WINC_{jt}) + \delta_2 ln(BINC_{jt}) + \delta_3 ln(PINC_{jt}) + \delta_4 ln(TINC_{jt)} + \varphi REFRI + \gamma_1 HHS_{jt} + \gamma_2 HHL_{jt} + \gamma_3 HS_{jt} + \gamma_4 EDUC_{jt} + \gamma_5 STUD_{jt} + \epsilon_{ijt} \quad (\mathbf{2})$$

where subscripts (i, j, t) represent food group, province, year, respectively; Q refers to the consumption of each food group; GRAINP, FATOILP, MEATP, EGGP, SEAFOODP, VEGEP, FRUITP are grain price, fat oil price, meat price, egg price, seafood price, vegetable price, fruit price; RINC is rural income; WINC, BINC, PINC, TINC are different composites of rural income, denoting income from wage, family business, property, transfer; REFIR represents the number of refrigerator ownership per 100 household; and household characteristics include household size (HHS), the percentage of people with high school degree and above (EDUC), house area per capita (HS), arable land size per household(LS), and students number per household (STUD).

Based on Engel's Law, consumers increase their expenditures for food products less than their increases in income. So in equations (1) and (2), we use a logarithm form for income term. In addition, in equation (2), logarithms of wage income, family business income, property income,

transfer income are used instead of total rural income per capita in equation (1), which can be helpful in explaining the effect of different income source on meat consumption.

**b. Demand system**

The AIDS model was firstly proposed by Deaton and Muellbauer (1980) and appears to be both popular and effective in food demand analysis. Our model specification is as follows:

$$w_{ipt} = \alpha_i + \sum_{j=1}^{n} \gamma_{ij} \ln(P_{jt}) + \beta_i \ln\left(\frac{M}{P}\right) + t_i * trend + r_i * refri_{pt} + \sum_{i=1}^{n} h_{ik} X_{kpt} + \varepsilon_{ipt}$$

where subscripts i and j indicate the studied food groups (grain, fat&oil, meat, eggs, seafood, vegetables, fruits), and p, t indicated the different provinces and different year respectively. X represents household characteristics: household size (HHS), the percentage of people with high school degree and above (EDUC), house area per capita (HS), arable land size per household (LS), students number per household (STUD), the number of household member in labor market, and k is from 1 to 6.

The non-linear AIDS price index (P) is defined as

$$\ln(P) = \alpha_0 + \sum_j \alpha_i \, lnp_j + \frac{1}{2} \sum_j \sum_i \gamma_{ij} \, lnp_i lnp_j \, .$$

The adding-up restrictions are imposed as:

$$\sum_i^n \alpha_i = 1; \sum_i^n \beta_i = 0; \sum_i^n \gamma_{ij} = \sum_j^n \gamma_{ij} = 0; \sum_i^n t_i = 0; \sum_i^n r_i = 0; \sum_i^n h_{ik} = 0$$

The Slutsky symmetry restriction is $\gamma_{ij} = \gamma_{ji}$.

## Results

### (1) Demand equation results

In all four specifications of the meat demand equation (not system, discussed below), we find a sizable, negative, and statistically significant effect of refrigerator ownership on at home meat consumption in rural areas. For example, the entry in the third column of Table 2 indicates that a 1 unit increase in the ownership of refrigerator every 100 household will be associated with 0.082 unit decrease in at home meat consumption in rural areas. In contrast, Lyon and Durham (1999) found that refrigerator ownership has positive effect on at home meat consumption for urban population in China.

In addition, the rural meat demand equation estimates indicate a sizable, negative, and statistically significant effect of meat price on at home meat consumption. This negative coefficient demonstrates that meat is greatly responsive to price change, and this result is consistent with the findings of previous studies (Yen et al. 2004). Moreover, our results indicate that income has a statistically significant, large, and positive effect on meat consumption at home in rural areas. The outcome of a strong income impact on meat consumption is in line with previous findings (Yu and Abler, 2009). When we separate rural income per captain into wage income, family business income, property income, and transfer income, we find that wages income has much bigger effect on meat consumption at home in rural areas compared to income from other sources. This finding suggests that sensitivity to income might be further explored in future research by disaggregating income sources, as discussed below.

**Table 2 the regressions results of meat consumption with different equations**

| | OLS | | FE | |
|---|---|---|---|---|
| **Independent Variables** | **(1)** | **(2)** | **(3)** | **(4)** |
| Grain Price | -4.34<br>(1.97)** | -4.11<br>(2.09)* | 1.62<br>(2.02) | 1.83<br>(2.04) |
| Fatoil Price | 0.54<br>(0.24)** | 0.67<br>(0.24)*** | 0.059<br>(0.17) | 0.012<br>(0.179)* |
| Meat Price | -0.50<br>(0.18)*** | -0.61<br>(0.17)*** | -0.236<br>(0.117)** | -0.21<br>(0.12)* |
| Egg price | 2.93<br>(0.48)*** | 2.34<br>(0.51) | -0.70<br>(0.453) | -0.81<br>(0.47)* |
| Seafood Price | -0.065<br>(0.13) | 0.06<br>(0.15) | 1.52<br>(0.419)*** | 1.47<br>(0.43)*** |
| Vegetable Price | -1.61<br>(0.93) | -2.86<br>(1.05) | -1.19<br>(0.94) | -1.26<br>(0.94) |
| Fruit Price | -0.22<br>(0.91) | -0.53<br>(0.92) | -0.344<br>(0.85) | -0.545<br>(0.87) |
| Ln(Income) | 0.0048<br>(0.0008)*** | | 0.0015<br>(0.0006)** | |
| Wage Income | | 0.0026<br>(0.0012)** | | 0.0025<br>(0.001)** |
| Business income | | 0.007<br>(0.0015)*** | | 0.0012<br>(0.0009) |
| Property Income | | 0.138<br>(0.0.01) | | 0.0010<br>(0.0050) |
| Transfer Income | | 0.026<br>(0.006)*** | | -0.0017<br>(0.0032) |
| Refrigerator ownership | -0.19<br>(0.05)*** | -0.25<br>(0.053)*** | -0.082<br>(0.028)*** | -0.080<br>(0.028)*** |
| Household Size | 1.56<br>(4.05) | -2.04<br>(4.04) | -7.22<br>(2.28)*** | -7.61<br>(2.32)*** |
| Household Labor | 4.43<br>(5.53) | 8.85<br>(5.63) | -0.76<br>(2.46) | -0.93<br>(2.50) |
| Education Level | -0.36<br>(0.05)*** | -0.36<br>(0.05)*** | 0.15<br>(0.063)** | 0.16<br>(0.064)** |
| Land Size | 0.29<br>(0.19) | -0.59<br>(0.26)** | 0.92<br>(0.46)** | 1.47<br>(0.61)** |
| Students | -3.01<br>(4.65) | 0.57<br>(4.52) | 1.25<br>(2.47) | 1.76<br>(2.52) |
| Adjusted R-square | 0.55 | 0.59 | 0.96 | 0.95 |

Notes: *** denotes significance at the 1% level, **denotes significance at the 5% level, and * denotes significance at the 10% level.

Compared to OLS regressions, fixed effect models have high adjusted R-square, up to 0.96, indicating that fixed-effect model can explain rural meat consumption at home in China very well. The fixed effect approach generates uniformly smaller estimates for the parameters of own-price, income, and refrigerator ownership compared to OLS regression. At least two explanations for the difference between the OLS and fixed effect estimates exist. First, each province has its

own specific characteristics as regards land resources, climate, water resources, and culture. Cultural differences, in particular, might include general preferences for foods eaten at home that lead in turn to different responses to economic factors and refrigerators. Second, the government varies policy among provinces from east to west. For instance, reforms that began in 1978 started with the provinces in eastern part of China, along the coast.

The regression estimates with fixed-effects in column (4) represent our main results. The findings are generally consistent with our expectation that meat demand at home substitutes with fat&oil and seafood, as shown in the results that the coefficient on prices of these foods are positive. At home meat demand is complementary with eggs, vegetables, and fruits, as all the coefficients on these food prices are negative. The coefficient of meat price is statistically significant at the 5% level with a value -0.21, which means that a real meat price increase of 1 unit will bring about a 0.21 unit reduction in meat consumption. The coefficient of seafood price is also statistically significant at the 1% level with the value 1.47, which means that seafood price increases 1 unit will cause 1.47 unit increase in meat consumption perhaps because meat and seafood are very important sources of protein in food. Among different sources of income, wage income is a major influencing driver in meat consumption. The coefficient of wage income is 0.0026, which is statistically significant at the 5% level.

## (2) Demand System Results

In the estimation of an AIDS model representing at home food demand in rural China, in the first version, we include prices of different food group, expenditure and refrigerator ratio per one hundred. In the second version, we add trend to the estimation. In the third version, we add household characteristics to the estimation. From Table 4, without household characteristics, the signs of coefficients for the refrigerator ownership are consistent for the first and second versions: negative signs for grain, fat&oil, and meat expenditure shares. However, with household characteristics in the model, refrigerator ownership has positive effect on the expenditure shares of fat&oil, meat, egg, seafood, but has negative effect on the expenditure shares of grains and vegetables.

From Table 5, after including household characteristics, the own-price elasticity for seafood is the least inelastic, at -0.74, with meat in the second place, with -0.51. These estimates suggest that that meat and seafood are more price responsive for rural at home food demand as compared to other foods. Egg and fat&oil lie in the third and fourth place with own-price elasticities of -0.47 and -0.45 respectively. The own-price elasticity of grain is -0.38, which is more inelastic than at home demand for vegetables and fruits in rural areas.

Table 5 represents expenditure elasticity estimates. The results for several commodities vary depending on specification. However, expenditure elasticities are consistently greater than one

for at home meat and egg demand in rural areas and grain demand expenditure elasticities are consistently less than one in these results.

**Table 3 the parameter estimates of AIDS model with three stages**

| | (1) | (2) | (3) | | (1) | (2) | (3) |
|---|---|---|---|---|---|---|---|
| γ11 | 0.342 (0.041)*** | 0.333 (0.038)*** | 0.227 (0.033)*** | α1 | 0.681 (0.023)*** | 0.639 (0.031)*** | 0.768 (0.036)*** |
| γ12 | -0.079 (0.009)*** | -0.066 (0.009)*** | -0.015 (0.009) | α2 | 0.088 (0.012)*** | 0.048 (0.021)** | -0.341 (0.016)*** |
| γ13 | -0.141 (0.031)*** | -0.127 (0.029)*** | -0.121 (0.025)*** | α3 | 0.184 (0.019)*** | 0.297 (0.022)*** | 0.523 (0.035)*** |
| γ14 | 0.028 (0.008)*** | 0.019 (0.008)** | -0.005 (0.006) | α4 | -0.026 (0.010)** | -0.089 (0.013)*** | 0.127 (0.017)*** |
| γ15 | -0.091 (0.009)*** | -0.084 (0.008)*** | -0.016 (0.010) | α5 | 0.031 (0.010)*** | 0.065 (0.015)*** | -0.389 (0.022)*** |
| γ16 | -0.044 (0.015)*** | -0.051 (0.015)*** | -0.075 (0.012)*** | α6 | 0.014 (0.010) | -0.065 (0.020)*** | 0.409 (0.02)*** |
| γ17 | -0.016 (0.007)** | -0.024 (0.008)*** | 0.005 (0.008) | α7 | 0.027 (0.006)*** | 0.105 (0.016)*** | -0.096 (0.015)*** |
| γ22 | 0.023 (0.007)*** | 0.023 (0.007)*** | 0.021 (0.006)*** | β1 | -0.029 (0.003)*** | -0.029 (.00328)*** | -0.015 (0.006)** |
| γ23 | 0.021 (0.009)** | 0.010 (0.009) | 0.009 (0.009) | β2 | -0.004 (0.001)*** | -0.004 (0.001)*** | 0.004 (0.002)** |
| γ24 | 0.010 (0.004)** | 0.021 (0.005)*** | 0.009 (0.004)** | β3 | 0.017 (0.003)*** | 0.017 (0.003)*** | 0.008 (0.005) |
| γ25 | 0.023 (0.004)*** | 0.011 (0.004)** | 0.003 (0.005) | β4 | 0.003 (0.001)*** | 0.003 (0.001)*** | 0.001 (0.001) |
| γ26 | 0.007 (0.005) | 0.010 (0.005)** | -0.011 (0.005)** | β5 | -0.001 (0.00113) | -0.001 (0.001) | 0.005 (0.002)** |
| γ27 | -0.005 (0.004) | -0.010 (0.004)** | -0.016 (0.004)*** | β6 | 0.013 (0.002)*** | 0.013 (0.001)*** | -0.006 (0.003)** |
| γ33 | 0.178 (0.033)*** | 0.161 (0.033)*** | 0.161 (0.026)*** | r1 | -0.0024 (0.0005)*** | -0.0009 (0.001) | -0.0020 (0.001)*** |
| γ34 | -0.008 (0.008) | -0.008 (0.009) | -0.012 (0.007)* | r2 | -0.0002 (0.0001) | -0.0002 (0.0001) | 0.0006 (0.0001)*** |
| γ35 | -0.002 (0.008) | 0.003 (0.007) | 0.003 (0.009) | r3 | -0.0003 (0.0004) | -0.001 (0.0005)** | 0.0010 (0.0006)* |
| γ36 | -0.043 (0.013)*** | -0.035 (0.014)** | -0.037 (0.011)*** | r4 | 0.0009 (0.0001)*** | 0.0008 (0.0001)*** | 0.0004 (0.0001)*** |
| γ37 | -0.005 (0.007) | -0.003 (0.008) | -0.003 (0.009) | r5 | 0.0007 (0.0001)*** | 0.0009 (0.0001)*** | 0.0014 (0.0002)*** |
| γ44 | -0.010 (0.006) | -0.019 (0.007)** | 0.019 (0.006)*** | r6 | 0.0010 (0.0002)*** | 0.0004 (0.0003) | -0.0013 (0.0003)*** |
| γ45 | 0.013 (0.003)*** | 0.022 (0.004)*** | 0.004 (0.004) | | | | |
| γ46 | -0.025 (0.004)*** | -0.032 (0.005)*** | -0.006 (0.004)* | | | | |
| γ47 | -0.008 (0.004)** | -0.003 (0.004) | -0.009 (0.003)*** | | | | |

| | | | |
|---|---|---|---|
| γ55 | 0.032<br>(0.005)*** | 0.021<br>(0.005)*** | 0.010<br>(0.007) |
| γ56 | 0.027<br>(0.004)*** | 0.028<br>(0.004)*** | 0.002<br>(0.005) |
| γ57 | -0.001<br>(0.003) | -0.001<br>(0.004) | -0.007<br>(0.005) |
| γ66 | 0.080<br>(0.010)*** | 0.077<br>(0.011)*** | 0.126<br>(0.009)*** |
| γ67 | -0.002<br>(0.004) | 0.003<br>(0.004) | 0.000<br>(0.005) |
| γ77 | 0.036<br>(0.005)*** | 0.038<br>(0.005)*** | 0.030<br>(0.006)*** |

Note: (1) without trend and household characteristics; (2) with trend and without household characteristics; (3) with trend and household characteristics; *** denotes significance at the 1% level, **denotes significance at the 5% level, and * denotes significance at the 10% level.

**Table 4 the Marshallian Elasticity and Expenditure Elasticity with three stages**

| | **Marshallian Elasticity Matrix** | | | | | | | **Expenditure Elasticity** |
|---|---|---|---|---|---|---|---|---|
| | **grain** | **fatoil** | **Meat** | **egg** | **seafood** | **vege** | **fruit** | |
| | (1) Without trend and without household characteristics | | | | | | | |
| Grain | -0.02 | -0.21 | -0.37 | 0.08 | -0.25 | -0.11 | -0.04 | 0.92 |
| Fatoil | -2.05 | -0.38 | 0.58 | 0.26 | 0.63 | 0.20 | -0.12 | 0.88 |
| Meat | -0.47 | 0.06 | -0.46 | -0.02 | -0.01 | -0.14 | -0.02 | 1.05 |
| Egg | 0.74 | 0.26 | -0.23 | -1.29 | 0.35 | -0.70 | -0.22 | 1.09 |
| Seafood | -2.39 | 0.61 | -0.06 | 0.34 | -0.15 | 0.70 | -0.03 | 0.98 |
| Vege | -0.33 | 0.04 | -0.29 | -0.16 | 0.17 | -0.50 | -0.01 | 1.08 |
| Fruit | -0.37 | -0.11 | -0.13 | -0.18 | -0.03 | -0.04 | -0.17 | 1.02 |
| | (2) With trend and without household characteristics | | | | | | | |
| Grain | -0.02 | -0.21 | -0.37 | 0.08 | -0.25 | -0.11 | -0.04 | 0.96 |
| Fatoil | -2.05 | -0.38 | 0.58 | 0.26 | 0.63 | 0.20 | -0.12 | 0.98 |
| Meat | -0.47 | 0.06 | -0.46 | -0.02 | -0.01 | -0.14 | -0.02 | 1.01 |
| Egg | 0.74 | 0.26 | -0.23 | -1.29 | 0.35 | -0.70 | -0.22 | 1.19 |
| Seafood | -2.39 | 0.61 | -0.06 | 0.34 | -0.15 | 0.70 | -0.03 | 0.95 |
| Vege | -0.33 | 0.04 | -0.29 | -0.16 | 0.17 | -0.50 | -0.01 | 1.09 |
| Fruit | -0.37 | -0.11 | -0.13 | -0.18 | -0.03 | -0.04 | -0.17 | 0.87 |
| | (3) With trend and household characteristics | | | | | | | |
| Grain | -0.36 | -0.04 | -0.32 | -0.01 | -0.04 | -0.20 | 0.01 | 0.96 |
| Fatoil | -0.46 | -0.45 | 0.21 | 0.24 | 0.09 | -0.32 | -0.42 | 1.12 |
| Meat | -0.39 | 0.03 | -0.51 | -0.04 | 0.01 | -0.12 | -0.01 | 1.02 |
| Egg | -0.16 | 0.25 | -0.33 | -0.47 | 0.12 | -0.17 | -0.26 | 1.02 |
| Seafood | -0.48 | 0.08 | 0.04 | 0.11 | -0.74 | 0.03 | -0.18 | 1.13 |
| Vege | -0.46 | -0.07 | -0.22 | -0.04 | 0.01 | -0.19 | 0.00 | 0.96 |
| Fruit | 0.07 | -0.36 | -0.10 | -0.22 | -0.16 | -0.01 | -0.32 | 1.08 |

## Discussion

### (1) Refrigerator

The estimates of refrigerator ownership are negative from all our specifications of a single meat demand equation. This result for at home meat demand in rural areas is opposite the findings of at least some previous research (Lyon and Durham, 1999) and even contrary to our initial hypothesis. Refrigerator ownership has a negative effect on at home meat demand in rural areas in two of the demand specifications and a positive effect on meat expenditure in a third and more elaborate specification. In contrast, a more firm finding of a positive impact on meat expenditure would be consistent with Gale et al. (2005). However, the previous studies are not entirely comparable. Lyon and Durham (1999) focus on urban consumers and there is no overlap between their data period and the 2001-2010 period we use for our estimates. The regional focus of this study and Gale et al. (2005) overlap, but their data ends in 2001 which is when our own only starts and, perhaps more fundamentally, they do not use price data in their estimation.

Nevertheless, the tendency in our examination to find a negative impact of refrigerator ownership on at home meat demand begs questions. We offer two possible explanations for the contrary sign of refrigerators. First, food waste might decreases significantly in rural China when people have refrigerators. For instance, it might be the case that they cooked more food than what they consumed for each meal before owning a refrigerator, partly in order to save time for work. The surplus food sometimes went bad without refrigerators, requiring that it be thrown away or fed to livestock or poultry. After households have refrigerators, they can keep food safe for a while, and also make good plan for meals every day.

A second possibility is that this result is a consequence of some limitation of the data or specification. Many of the data series are correlated, suggesting that there might be multicolinearity, although this would not bias parameters and should not explain a consistently negative estimated effect if the real relationship is positive. As for data, the reliability of data can always be questioned, but the reliance of previous studies on this source for survey data suggest that there might not be a better option for applied economic assessment of rural at home food demand in China, at least not at present.

### (2) Income

What we found from our results of the four versions of single equation demand emphasize that income plays an important role in determining the growth in at home meat consumption in rural China, especially wage income. People living in rural area often depended on family operating or business income from land, typically income from agriculture, fishery, forestry, or horticulture.

However, due to labor policy changes, farmers can find jobs in factories, firms, or the service sector so that they can obtain stable wage income, which contributed to the increase in rural meat consumption at home. Another possible reason for the different effects by income sources is that they might serve as a proxy for income distribution in some sense. These data are aggregated at the province level, so if a particular source of income tends to go to consumers whose income elasticity of at home meat demand is highest, then the coefficient on this income source estimated on our panel data (of province and time) might tend to be higher than for other income sources. In contrast, if another income source tends to go to consumers whose income elasticity of at home meat demand is lowest, then the estimated coefficient on this income source might tend to be lower than for other income sources.

**(3) Price**

The estimates from all specifications of the one-equation demand indicated that at home meat demand in rural China is elastic. In addition, seafood price was estimated to have a large impact. However, meat consumption is not found to be very sensitive to price variation in grain, vegetables, and fruits if judged on the versions of the single-equation demand.

The demand system estimates suggest that at home meat expenditure share in rural China is inelastic with respect to its own price. Estimated grain price effects in the system approach suggest that grains substitute for at home meat demand in rural China, and this result might follow from the large share of expenditure devoted to grains and the fixed total expenditure.

**(4) Demographic factors**

The estimation results suggest that demographic factors play a large part in explaining the variation in at home meat consumption in rural areas, especially household size, education level, and land size. At home meat consumption in rural China tends to fall as household size grows. However, at home meat consumption is higher for rural people who have higher education level, perhaps because higher education can contribute to higher income. In addition, households with bigger land size are more likely to consume more meat at home in rural areas, possibly because land size represents the resource endowments. Finally, it could be that rural households with more students tend to consume more meat at home if it is the case that some parents believe that meats provide important nutrition.

## (5) Areas for further research

There are many areas for further research in this area. Here, we list several that seem most promising or most pressing.

First, although our current study addresses the effect of refrigerator ownership on meat and consumption at home, we should be able to better understand the refrigerator effect on total meat consumption if related data and studies about meat consumption away from home are accessible in the future.

Second, refrigerators should have different effects on food consumption in the short and long run. This might suggest different statistical methods, but also different implications for applied analysis of Chinese food demand. For example, a regression discontinuity approach might be promising to test the impacts of refrigerators in the short run if rural household data about food consumption and refrigerator ownership are available. For the long run, refrigerator ownership might have minor or no effect on food consumption if tested using this approach. In applied terms, the distinction between refrigerator ownership and other factors, like income or underlying trends, might not be very important for analysis over a very short period of time, such as within a marketing year. However, applications that extrapolate into the farther future risk misallocating the role of refrigerator onto other factors, potentially biasing estimated of long run food demand. Further research might be usefully take account of the data period and the purpose.

Third, incorporating refrigerator use in projections of food consumption in rural China is an important area of future research. The average number of refrigerators per hundred households was less than 50 at present in 2010. In the next ten years, how will the refrigerator ownership rate change? With the increase in the refrigerator ownership, will there be some change in meat consumption in rural China? Going further, as refrigerator ownerhip and other factors cause commodity demands to evolve over time, how will this process help to shape the broader commodity markets, including supplies, prices, and trade, in the future? What will be the implications for China's domestic food and farm policies, and for China's trade profile with respect to global markets?

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