Analyzing the Size and Affecting Factors of Household Food Waste in China

J.-Q. Jiang[1]; T. Yu[2]; Z.-H. Wang[1]; D.-M. Qi[3]; W.-Z. Huang[1]

1: Shenyang Agricultural University, , China, 2: University of Tennessee, , United States of America, 3: Quzhou University, , China

Corresponding author email: tyu1@utk.edu

Abstract:

Although food waste has become an increasingly important issue in China, little attention has been given to its scale and determining factors in the related literature of food waste. This study uses the China Health and Nutrition Survey (CHNS) data surveyed in 1991, 2000 and 2009 to investigate the food waste behavior of Chinese households over the twenty years. In addition, the factors affecting food waste at home were identified and evaluated using the double hurdle model. The survey results show that the food waste amount at home per household has declined over the study span, likely due to the increase of outside-dining, while the percentage of households incurring food waste was on the rise. Also, among the factors associated with household food waste, the household size and regional differences in dietary habits were found positively correlated with food waste over time. In addition, the high-income families tended to generate more waste than low-income families after 2000. The age, education and employment characteristics of the main female member were also related with household food waste although the impact on food waste varied over time.

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Abstract: Although food waste has become an increasingly important issue in China, little attention has been given to its scale and determining factors in the related literature of food waste. This study uses the China Health and Nutrition Survey (CHNS) data surveyed in 1991, 2000 and 2009 to investigate the food waste behavior of Chinese households over the twenty years. In addition, the factors affecting food waste at home were identified and evaluated using the double hurdle model. The survey results show that the food waste amount at home per household has declined over the study span, likely due to the increase of outside-dining, while the percentage of households incurring food waste was on the rise. Also, among the factors associated with household food waste, the household size and regional differences in dietary habits were found positively correlated with food waste over time. In addition, the high-income families tended to generate more waste than low-income families after 2000. The age, education and employment characteristics of the main female member were also related with household food waste although the impact on food waste varied over time.

Keywords: food waste; Chinese household; China Health and Nutrition Survey; double hurdle model

1 Introduction

The world-wide food loss and waste[1] has become a serious issue to food sustainably. An estimated 1.3 billion tons of food were lost or wasted annually in production, manufacture distribution, and at homes, accounting for nearly 32% of global food production (Gustavsson et al., 2011; BCFN, 2012). Calculated with calorie, this amounts to approximately 24 percent of all food produced, which means that one out of every four food calories intended for people is not ultimately consumed (Lipinski et al, 2013). Over time, a study on several FAO projects focusing on post-harvest losses and waste during the 1980s and 1990s shows, after two decades, the post-harvest losses and wastes ranged from 13 to 22% of the production in the case of rice, from 15 to 18% for maize, from 8 to 27% for millet and sorghum (Segrè et al., 2014). And such a huge amount of food wastage each year has many negative consequences. It not only directly reduce the actual global food supply, contributes towards increases in global food prices, and aggravate the food crisis in developing countries, but also indirectly cause substantial negative economic and environmental effects (Graham-Rowe et al., 2014; Göbel et al., 2015). Economically, food wastage represent a waste of resources used in agricultural production such as water and arable land, and potentially reduce the income of agricultural producers and increase consumer spending; on the environment, food wastage has significant contribution in greenhouse gas emissions, and lead inefficient utilization of global water and land resources, and finally increase ecological tensions (Gustavsson et al., 2011; Quested et al., 2013).

Due to the progressively negative social, economic and environmental impact of food wastage, it has attracted recent attention of government and the public (Kummu et al., 2012; Beretta et al., 2013; Evans, 2012; Quested et al., 2013; Jörissen et al., 2015). Most of those studies primarily focused on the food waste issues in developed countries (e.g. Parfitt et al., 2010; Dorward, 2012), while much less attention has been given to developing countries or emerging economies, such as China. Benefited from the double-digit annual high-speed economic growth since reform and opening-up policy in the late 1970s, China has become a most important emerging economy in the world. In the transition from a developing agricultural country to a developed industrial country, along with economic development and improvement of people's living standards, the attitudes of consumption and behavior patterns of Chinese people has undergone profound changes. Food waste by consumers then became more common and serious. From a survey in eight Chinese pilot cities in 2008, food waste generated in the city every day takes up a high share in municipal solid waste (MSW), roughly ranging from 51.1% to 74.63% (Tai et al., 2011; Liu, 2014). A study from Institute of Geographic Sciences and Natural Resources Research shows that 17-18 million tons per year of food have been discarded in catering sectors over the period of 2013−2015, equivalent to the annual total amount of food ration of 30-50 million people (Du, 2016). Another survey completed by College of Food Science and Nutritional Engineering, China Agricultural University indicates, between 2006-2008, China's annual food waste could feed 250 -300 million peoples (Wang, 2010). Responded to the increasingly severe of food waste, Chinese government has launched an "Empty Plate" campaign to reduce food waste.

[1] In this paper, "food loss and waste" (together called food wastage) consists of food loss and food waste along the food supply chain (FSC). In the definitions, "Food loss" refers to food that spills, spoils, incurs an abnormal reduction in quality such as bruising or wilting, or otherwise gets lost before it reaches the consumer. Food loss typically occurs at the production, storage, processing and distribution phases of the FSC, and is the unintended result of agricultural processes or technical limitations in storage, infrastructure, packaging, and/or marketing. "Food waste" refers to food that is of good quality for human consumption but that does not get consumed because it is discarded—either before or after it spoils. Food waste typically, but not exclusively, occurs at the retail and consumption stages in the FSC and is the result of negligence or a conscious decision to throw food away (Lipinski et al., 2013).

Despite of the surging issue of food waste and loss in China, empirical analysis on its affecting factors remain scarce. Currently, food waste[2] at home is less than the level from catering service sectors; however, the experience of developed countries shows that the size and relative proportion of household food waste will continue to rise. Therefore, this paper aims to study the size and affecting factors to household food waste in China over time. In the study, the Tobit model and double hurdle model were applied to the China Health and Nutrition Survey (CHNS) data that surveyed in 1991, 2000 and 2009 empirical investigate the determinants of household food waste at household levels, and identify their change over time. Our study contributes to the related literature in two dimensions: first, it expands the international empirical research of food waste from developed countries to developing countries. Secondly, through the comparison of the empirical results of 1991, 2000 and 2009, we can sketch out the dynamic changes of household food waste in the process of social and economic transformation in China, which could provide reference for household food waste issue in other emerging economies.

The remainder of this paper is structured as follows: Section 2 gives a brief literature review of food wastage, and provides a conceptual framework of household food waste. Section 3 introduces the data sources, model and estimating methods, while Section 4 reports the statistical descriptions and regression results. Finally, Section 5 presents the conclusions and proposes policy implications.

2 Literature Review of Household Food Waste

The issue of food wastage is a fairly new research topic, despite there has been increasing awareness worldwide towards the loss and waste of food in recent years (Evans, Campbell and Murcott, 2013; Secondi, Principato and Laureti, 2015). The existing literatures of food wastage are grouped into two categories. The first is the quantification and statistical analysis of food wastage (Engström and Carlsson-Kanyama, 2004; Langley et al., 2010; Quested et al., 2011; Beretta et al., 2013; Bräutigam, Jörissen and Priefer, 2014; Garrone, Melacini and Perego, 2014; Liu et al., 2016). Generally, most of studies in this type, start from constructing a calculation methodology of food wastage depending on the definition and the assumptions made, quantify the scale of food wastage across the entire FSC from initial production to final consumption and with differentiation by product group, and make assessment of data reliability. The Second category discuss people's awareness, attitudes and behaviors to food waste and their affect factors (Barr, 2007; Quested et al., 2013; Neff et al., 2015; Secondi, Principato and Laureti, 2015). In general, these studies aim at exploring the phenomenon of household food waste in developed countries within a specific conceptual framework from behavioral theories and empirical analyze the factors that shape the individuals' attitudes, behaviors toward food waste in the home or in the consumption.

As Quested et al. (2013) stated, there are many reasons why food is wasted and multiple behaviors that lead to such waste. Therefore it is not an easy task to find a "one fits all" conceptual framework concerning this issue (Secondi, Principato and Laureti, 2015). In fact, there are very few publications have theoretical explored these multiple activities associated with food waste in home. The conceptual multiple-factors framework developed by WRAP (Waste

[2] In the definition of Gustavsson et al. (2011), the food waste refers to the food thrown away in the final consumption. According to the locate of food waste, it can divide in to food waste in the home (called it as "household food waste") and food waste outside the home such as wasting in the catering services or staff canteens (called it as "catering food waste"). In this paper, we use the definition of Gustavsson et al. (2011) to define the household food waste.

and Resources Action Program, UK) is the first groundbreaking and outstanding work in this field (Quested et al., 2011; Quested et al., 2013), and has become the theoretical basis for the most recent empirical studies on food waste. Essentially, WRAP framework is a derivative of the Theory of Reasoned Action (TRA) and its follow-up version Theory of Planned Behavior (TPB), is a conceptual framework of environmental behavior which based on the core logic of "Attitude-intention-behavior" (Barr, 2007). In the WRAP framework, the amount of household food waste is explained by the retail supply chain factors, individuals and households factors and the context in which the effects of retail supply chain factors and individuals and households factors are affected (Quested et al., 2011; Quested et al., 2013). Among them, the retail supply chain factors include shelf life, formulation of the product, production methods, packaging functionality and labeling, storage conditions, marketing and price promotions in the retail stage. The individuals and households factors contain individuals' attitudes and values, motivation, habits, knowledge and skills, awareness and perceived social norms etc. Derived from this framework, some scholars refined the factors used to explain food waste behavior into two levels of individual level and area level. And the individual level factors are demographic and socio-economic characteristics, attitudes, habits and motivations related to the use of resource, waste and food waste issue; the areal level factors cover economic, socio-cultural and environmental characteristics of the country (area) in which the individuals or their households reside (Secondi, Principato and Laureti, 2015).

From the results of surveys in developed countries, there are five major causes of food waste at consumer/households level often mentioned: (1) poor planning of purchases often leading to buying more than is needed – impulsive or advance purchasing of food that is not required immediately; (2) discarding food due to confusion over "best-before" and "use-by" dates; (3) poor storage or stock management in the home; (4) excess portions prepared and not eaten; (5) poor food preparation techniques often leading to less food being eaten or food quality losses and waste due to the preparation method, or lack of knowledge on how to use leftovers more efficiently instead of discarding (WRAP, 2008, 2009; HLPE, 2014). Also, previous researches revealed that, the above five causes are closely related with four types of factor: household size and population structure, socio-economic status and demographic characteristics in household level and cultural and consuetude context in area level (Parfitt, Barthel and Macnaughton, 2010; Secondi, Principato and Laureti, 2015).

Regarding the family size and structure, the existing studies found that the number of members, the number and proportion of children are significantly associated with household food waste. In terms of the household size, some studies concluded that it negative related with food waste in home. They considered that the demand for rich and diverse dishes in each meal and the minimum amount requirements of food ingredients in each dish make it is easy to purchase and cook excess food in small size families, therefore, more food waste occurred in these families. However, for large size families, the economies of scale in cooking make them less food waste (WRAP, 2008; Song et al., 2015). Other studies also suggest there is a positive relationship between household size and food waste (Parfitt, Barthel and Macnaughton, 2010). In the large size families, more food waste occurs because there is a high fluctuation in the number of members who dine at home and families usually prepare their meal according to their total number of members. In term of the number and proportion of children, families with many children are more likely to choose bulk discount goods such as "economic packages" when they purchase food, due to maximum the children nutritional needs under family budget constraint. And this can easily lead to over-purchase. Therefore, those families with more children may

discard more food. For Chinese families, we consider household size is inversely related to the amount of food waste in the home, and the positive association between the number of children and household food waste may be insignificant or even be negative. Under the "one-child" policy, Chinese parents and elder members in the family extremely spoil their children, and such spoiling would lead the "one-child" families to purchase more food than other families, and then waste more food (Song et al., 2015).

In terms of household income, the previous literatures reported it positively related with the amount of food waste (Schneider, 2008; Parfitt, Barthel and Macnaughton, 2010; Segrè et al., 2014). These researches suggested that, income growing not only enhance the purchasing power of households, but also cause household consumption values and behaviors change (Messori, 2010). And the increase of purchasing power and the change of consumption values and behaviors can easily trigger household over-purchase, and then cause food waste. Meanwhile, the increase of purchasing power can expands household's consumption choices and leads more information need for consuming decision-making. These increases the possibility that households make poor planning of purchases, and then lead households to buy more than is needed. In addition, in the traditional culture of many countries, plenty and diversity of food is a symbol of household wealth status. The rich families in these countries tend to over-phase food to highlight its wealth status, and then happen to waste food (IMECHE, 2013). For Chinese families, this logical relationship between household income and food waste may also exist. Therefore, this study suggests that household income positively associate with the amount of food waste in China.

The demographic and employment factors of key adult members in the family are found influential to household food waste (Schneider, 2007, 2008). The senior people are usually confused by "best before" and "used by" dates and then discard the food still be edible (Segrè et al., 2014). Also, they are easily attracted by price promotions such as "buy two get one" and "bulk discount" to over-purchase food and eventually lead to waste. In contrast, some studies suggested that the number of elder is positive related with food waste at home. Because of the low income, elder are more careful planning on the purchase of food and more saving, thus waste less (WRAP, 2008). In terms of the education degree of the key adult members, some studies show it is positive associated with the amount of food wasted (Schneider, 2007, 2008). These studies suggest that, the families that their key members (especially the household head) have higher education level can have a high-level income, and thus more likely to buy more food and waste more food. However, some studies argued that the key members with more education can plan good and rational on food purchasing and have more pro-environment behaviors, thus leading less possibility of over-purchase and food waste.

As for the employment characteristics of the key members, most studies found that the families that their key members have full-time job are more likely to have food waste (Schneider, 2007, 2008). Furthermore, some of these researchers found that, the full-time employment of the key male members is insignificant related with household food waste, while the main female members' full-time work has a positive impact on household food waste (Segrè et al., 2014). In the family, female adult members are the main undertaker of housework such as food cooking. If they work full-time, their opportunity cost of doing housework increases. To reduce the time spent on housework, they prone to buy pre-processed / semi-finished food for cooking. These pre-processed food, which usually have fixed-package to taste the requirements of standardization production and processing, are difficult to adapt to the differentiated needs of families and thus result in much more household food waste (WRAP, 2009). Based on the

previous findings, according to the real of China, we conclude that the relationship between household food waste and demographic factors of key adult members is ambiguous, while the full-time employment of the female adult member could increase the household food waste.

Finally, the existing literatures revealed that there is a great difference in household food waste among regions or countries due to the different culture and habits in food consumption (HLPE, 2014; Secondi et al., 2015). For China, the vast territory, the long history, the splendid culture and the very different regional environment of nature and geography have created distinctive dietary structures and consumption habits among regions. According to the staple food in the dietary structure and consumption habits, China can roughly be divided into the northern region dominated by pasta and the southern region dominated by rice. And the differences in dietary structures and consumption habits may result in obvious regional differences in household food waste. In addition, long-term urban-rural divide has resulted in a sharp difference of food consumption between Chinese urban and rural families, and then may lead to the different waste level between urban and rural household. Based on this, we believe that, due to the impact of culture, custom and dietary habits, there may have obvious north-south and urban-rural differences of household food waste.

3 Data, model and estimation methods

3.1 Data source

Data for this research was generated from the China Nutrition and Health Survey (CHNS). The CHNS is a large-scale sample survey conducted by the Carolina Population Center at the University of North Carolina and the National Institute for Nutrition and Health at the Chinese Center for Disease Control and Prevention. The first wave of the CHNS was collected in 1989 and has been repeated every two or three years. The food consumption and waste data in 1989 was incomplete and the definition of household food consumption and waste in the dietary sectors has changed since 2011, thus we selected three waves departing every 10 years (i.e. 1991, 2000, 2009) of CHNS to conduct empirical analysis. A total of nine provinces (Heilongjiang, Liaoning, Shandong, Jiangsu, Henan, Hubei, Hunan, Guangxi and Guizhou) were included in the dataset we used.

The data of household food consumption and waste come from the dietary section of CHNS. According to the provisions of "Professional Standard of the People's Republic of China – Dietary Survey Method (WS/T426-2013)", this data is collected by 24-hours recall method. And in this method, investigators would inquire the detailed dietary intake of the respondents' household in the past 24 hours prior to the survey, and obtain the food consumption and waste data through weighting the initial amount on hand, purchased or self-supplied, wasted[3] and remaining. As various types of food each day in Chinese households and greater differences in dietary structures among Chinese families, this dietary survey would be repeated in 3 days[4] to reduce sampling errors.

Before using this data to statistical description and econometric estimation, we clean the data as follows: at first, we drop the household observations that have missing value in key variables

[3] In the CHNS survey, the amount of food waste is actually a 3-day amount of food discard in the home. In terms of the statistical scale, food discard is greater than food waste because it contains the inedible parts (e.g. bones, egg shells, pineapple skins)arising from food preparation under normal circumstance (Segrè et al., 2014; WARP, 2008 ; Song et al., 2015). However, it is difficult to distinguish the inedible parts from the food discard amount in the surveying, so researchers often use the food discard amount to represent the food waste amount in the current researches, and also in this paper.

[4] The 3-day survey usually take place in a continuous 3 days (two working days and one rest day).

such as food consumption and waste; And then, we drop the household that their 3-day food consumption amount is less than 0 g or their 3-day waste amount is larger than 2500 g in order to reduce the impact of data outliers on the regression results. After the data cleaning, the valid households in wave of 1991, 2000 and 2009 are 2,972, 3,413 and 3,530.

3.2 Regression model

Based on the analytical framework in the literature, a general regression model for Chinese households' behaviors toward food waste was defined in Eq.1:

$$wasteamt = f(\alpha + \beta fsize + \gamma fincome + \delta\ fchar + \theta\ region + \rho Z) \text{ (Eq.1)}$$

in which $wasteamt$ is the amount of food waste in the home; $fsize$ is family size and structure, including the household population and the number of children in the family; $fincome$ is the variable of household economic status, Mainly household income; $fchar$ are the variables of demographical and employment characteristics of key adult members in the family, including the age, education and employment type of household head and the main female member[5]; and $region$ is contextual variable in the area where the family lived, including two dummy variables to indicate the northern-southern region and rural-urban residence. The definitions and descriptions of the variables are listed in Table 1.

3.3 Estimation Method

The behavior outcome of household on food waste is naturally determined by a two-step progressive decision from whether to waste (the occurrence of food waste) to how much to waste (the amount of food waste). Because many households choose non-waste at their first step, there are many zero-value units for the variable of household food waste. If we use OLS method directly to estimate the household food waste function as Eq.1 on the subset that their waste amount is larger than 0, selection bias may be existed. Due to this, most of the scholars at first will choose the sample selection method such as the Heckman model (Heckit method) for regression.

However, in terms of the CHNS, it is a random sample from the population of Chinese household, has covered the non-waste subset as well as waste subset. And this has excluded all of the selection mechanisms that result in nonrandom samples, such as the sample design and the behavior of the units being sampled, including nonresponse on survey questions and attrition from social programs. Therefore, it is improper /inappropriate for using the sample selection method such as Heckit method to estimate the household food waste function as Eq.1.

In a general sense, for these corner solution models, we not only interest in the discrete part of the distribution that generate the zero observations, but also in the continuous part that generate the positive observations. We not only interest in the partial effect of $E(y = 0|x)$, but also in the partial effect of $E(y|x, y > 0)$ (Pudney, 1989). Thus, we generally use the standard Tobit model or the double hurdle Model to regress. However, there are inconsistent in behavioral decision-making mechanisms that the Tobit model and the double hurdle model actually be addressed. When there is a single mechanism determines the choice between $y = 0$ versus $y > 0$ and the amount of y given $y > 0$, in particular, $\partial P(y > 0|x)/\partial x$ and $\partial E(y|x, y > 0)$ have the same sign, we usually apply the standard Tobit model to estimate. While the initial decision of

[5] In the households of male head, the main female member is the spouse of the head, while in the households of female head, the main female member is the female adult who has working ability in the family.

$y = 0$ versus $y > 0$ could be separate from the decision of how much y given that $y > 0$, an alternative that the double hurdle model should be adopted to regress (Wooldridge, 2010).

In the light of the most likely that the choice that whether to waste and the choice that how much waste are in a single behavioral mechanism, we use the standard Tobit method firstly to estimate the Eq.1. But, since we cannot rule out the possibility that these two choices are separable, we also report the double hurdle model estimation results. And based on the comparisons of the results of the Tobit method and the double hurdle method, we also confirm the robustness of the Tobit regression outcome.

4 Preliminary Results

4.1 Household food waste status and scale estimation

Table 2 shows the statistical results of food consumption and waste for all sample households. From the results of the three waves in Table 2, the food consumed and wasted in the home has been declining in time, and the average amount of consumption and waste has decreased from14,330 g and 5015 g in 1991 to 8,199.8 g and 266.6 g in 2009 respectively. Of course, these falls of household food consumption and waste does not indicate the overall food consumption and waste are in decreasing, and these also are inconsistent with the reality in China. For these, there are two explanations: First, it associated with the transformation of the dietary patterns. In the past, Chinese residents have chosen eating at home. But now, they increasingly chose eating outside such as eating in restaurants, staff canteens, or using the take-out services. And this has bring about the declining of household food consumption and waste in China. Second, it is related to the universal of refrigerators in the home, the convenience (facility) improvement of food purchasing and the development of food market. Among of these three factors, the former can help families preserve food that cannot be consumed immediately for a long time and then reduce the waste of food. The latter two could reduce the daily purchasing amount of food. Although the weight amount of household food consumption and waste are in the decline over time, the percentage of families that have food waste is rising; its value has from 56.4% in 1991 to 64.9% in 2009.

Table 3 is the statistical results of the household food consumption and waste by province and rural/urban. On the provincial level, the average household food consumption in Henan Province increased during 1991-2000 and then down during 2000-2009, whiles it has a downward trend in the other 8 provinces between 1991 and 2009; the average household food waste in Liaoning, Henan, Hunan, Guizhou Province increased during 1991-2000 and fell down during 2000-2009 respectively, whereas it declined all the time during 1991-2000 in the other five provinces; And finally, on the percentage of households that have wasted food, it raised between 1991 and 2000 and then decreased between 2000 and 2009 in Jiangshu Province, has been fell during the first period and then increased during the last period in Shandong Province, has been dropped in Heilongjiang Province during 1991-2009, and it has a upward trend in other 6 provinces between 1991 and 2009. On the rural-urban level, during 1991-2009, the average food consumption and waste in rural and urban households was on the down, and the ratio of household that have food waste was on the growth.

We further quantified the total size of household food waste (Table 4). First, from the annual amount per capita, each Chinese wasted 10.76 kg food in the home in 2009. This number is less than the result calculated in Song et al. (2015), which quantify food waste from nutrients also

with the CHNS data. In the estimation of Song et al. (2015), the Chinese waste 16 kg food in the home per capita each year. From an international comparison, although the level of household food waste in China significantly lower than the wastage in developed countries such as the U.S and EU-27 countries, it generally higher than the level in the vast majority of Asia and Africa countries. As the results reported by Gustavsson at al. (2011), the American and European discard 95-115 kg food per capita each year, and the Asian and African wasted 6-11 kg food per capita per year. Furthermore, if coupled with food that wasting outside the home, the food waste per capita in China would be significantly higher than other Asia and Africa countries, and the wastage distance from America and Europe countries would be shorten. Because, according to several newspaper reports, the food waste occurred in the catering sectors in China are obviously higher than the household food waste.

Second, as the total size, all Chinese families have wasted about 14.36 million tons food in 2009. In spite of that its size slightly lower than the size in the catering sectors, which has reached 17-18 million tons each year, a calculation from the Institute of Geographic Sciences and Natural Resources Research of CSA, it is also amazing. If adding up these two values as a conservative result, the overall annual food waste in China would reach the size of 30 million tons, is equivalent to the 4.87% of the grain output in 2016.

4.2 The determinants of household food waste and its dynamics change

4.2.1 The Tobit results

With the CHNS data surveyed in 1991, 2000 and 2009, we have used a standard Tobit method to estimate the model of Chinese household food waste as Eq.1 respectively, and their results listed in column (1) of Table 5. From the statistics of the Chi-square test (LR Chi^2) that test the overall significance of the equation modeling by the Eq.1, its values in each year has passed the test at the significance level of 1, and means that the regression model (Eq.1) has a powerful explanation to the food waste behaviors of Chinese households. In the following part, we focused on the Tobit results of Table 5 to discuss the effects of the household size and structure, the households' socio-economic status, the demographic characteristics and employment of key adults at the household level and the contextual factors at the area level on household food waste in China in the detail.

Firstly, from the results of 1991, for the demographic and employment characteristics of key adult members, the education and employment characteristics of the female key adult have passed the significant test, and represented that they have important effects on the amount of food waste. Specifically, compared to the illiterate group, the 3-day amount of food waste in the families that main female member has the education degree of primary school and the education degree of senior high school and higher level decreased by 107.141 g and 213.698 g; compared to the not-working group, the 3-day food waste in these two groups that main female member has a full-time off-farm job and part-time off-farm job respectively fall 257.21 g and 194.26 g , and this inconsistent with the theoretical expectation in section 2 . For the variables of household size and structure, the household size passed the significant test at 10% level, and its positive coefficient indicated the large size household waste more food than the small size one. For the contextual variables, the regional dummy variable that represents the regional difference of dietary structures and consumption habits passed the test at the 1% significant level, and its coefficient indicated the families in the southern region where the rice is the staple food in the diet waste more food than these families in the northern region.

Secondly, in 2000, compared with the illiterate group, the household group that main female member has a degree of junior high school wasted less food and their 3-day amount would be decreased 99.515 g , and the waste in other two groups is indifference with this reference group; compared with the not-working group, food waste in the group that main female member has a part-time off-farm job would increase 151.2 g. Concerning the household income, it passed the significant test at the 10% level, and its coefficient implied it positively related with household food waste. For the variables of household size and structure, there is a positive relationship between household size and food waste, and the households with a larger number of children younger than 16 years old have discarded more food. As the contextual factors, the regional variable also passed the significant test at the 1% level, and its effects was same as it in 1991.

Thirdly, in 2009, the older of the household head and the younger of the main female member, the less of the food waste in the home. The rich families wasted more food than the poor families. The larger size families discarded more food than the small size families. And the households in the southern region that has staple food with rice wasted more food than the northern counterpart.

Summarized the regression results in 1991, 2000 and 2009, we found that, the factors that impact the household food waste in China since 1990s show the following features: (1) the contextual variable that reflect regional differences of dietary structure and consumption habits and the household size are common factors in the time. They have a significant effect on household food waste in all three survey years; (2) with economic development, the positive association between household income and food waste has change from unobvious to obvious, and the food waste in high-income families become more serious; (3) the demographic and employment characteristics of the main female adult strongly related with the level of household food waste, but the characteristics variables which has a significant effect would vary with the time. And the demographic and employment characteristics of head could not explain anything.

4.2.2 The Robustness discussion

Consider the possibility that the decision whether to waste food and how much to waste are separable, we further apply the Hurdle model method to estimate the household food waste functions as Eq.1, and the regression results are shown in the double hurdle model column of Table 5. Different from the Tobit model method, the double hurdle model method has two tiers, the first tier is whether or not to waste a positive amount of food, the second tier describe the decision on how much to waste. Due to this, the estimation results of Hurdle model method in this paper have two parts in each survey wave. In the first tier, we excluded two variables of household size and the number of children younger than 16 years old in the regression equation.

Integrated the results of these two tiers in this Hurdle model, we can find that, every variable which has significant effect in the Tobit regression is almost even significant in the Hurdle regression and has the same sign. Just with the Hurdle model results in 1991 as an example, they showed that, the effects of the education and employment of main female adult member are mainly reflected in the first tier regression, and the effect of population size is mainly reflected in the second tier regression, the contextual regional variable has effect in both two tier regressions. Combined these two tiers results of the Hurdle model, they are exactly corresponding to the Tobit results, and therefore we thought that the Tobit results are robust in this paper.

5 Conclusions and policy implications

The current empirical studies of food waste are almost focusing on the developed countries, and there is no concern for developing countries. However, in many of the developing emerging economies like China, food waste is becoming a widespread and serious social problem during their rapid economic transition. And at the present, in these countries, waste has become a major source of food lost and waste. So, the food waste in developing countries also deserves researchers' attention. Due to this, we have used a sampling survey data from China to analyze the household food waste in this paper.

Using the CHNS data surveyed in 1991, 2000 and 2009, this study investigated the households' food wasteful behavior in China. The main findings includes: Firstly, the weight amount of Chinese household food waste is declining during 1991-2009 due to the increasing of outside-dining, but the percentage of households which have food waste is on the rise. Secondly, based on 2009 data alone, food waste in the home is at least 10.76 kg per capita per year, accounting for as much as a total size of 14.36 million tons. Coupled with the food waste in catering service sectors, a total of over 30 million tons of food waste is generated in China each year, at least 4.87% of the annual grain output. Thirdly, among the factors associated with household food waste, the contextual dummy which reflects the regional differences in dietary structure and consumption habits and household size are the common factors in time; the high-income families tend to produce more waste than low-income families after 2000; the demographic and employment characteristics of the main female member are related with household food waste while the characteristics of household head do not work, and the demographic and employment characteristics of the main female member which play a role in food waste vary with time.

From the empirical findings, we consider that, the important things to react to the household food waste in China are that the public should give great consciousness and attention to household food waste, the government should take social campaign such as "Empty Plate" to enhance the people's awareness of food saving and internalize food saving as a social norm that people should be complied with. And at the meantime, we even should adapt the following actions to reduce household food waste: first is encouraging producer to introduce diverse package size of food to accommodate different household size, and guiding family to reasonable purchasing and consumption; second is strengthen propagating and guiding for wealthy families to rise their awareness of saving and environment; Third is increasing the food conservation and recycling knowledge of the major female adults in particular the female elders, and therefore improving the food utilization; Fourth is that the Chinese local governments should reinforce the household food waste research, and design the anti-waste policies according to the local reality.

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Table 1 Variable definition and statistics

Variable	Definition	Mean	s.d
ifwaste	Whether household waste food or not (0:no; 1:yes)	0.65	0.48
wasteamt	Household food waste amount over three days (gram)	88.42	136.20
hhsize	Household size (number of population)	3.36	1.49
youthn	Number of children 16 years old or younger in the family	0.49	0.73
lhincg	Family economic status (logarithm of Chinese Yuan)	10.07	1.07
hage	Age of household Head	54.60	11.73
hedu	Education of household head (0:illiterate; 1:primary school; 2:junior high school; 3:high school and above)	1.64	1.07
hifwork	Employment of household head (0: unemployed; 1: working)	0.63	0.48
fage	Age of the main female member in the families	52.87	11.62
fedu	Education of the main female member in the family (0:illiterate; 1:primary school; 2:junior high school; 3:high school and above)	1.31	1.11
ffulwork	Employment of the main female member in the family (0: unemployed; 1: part-time off-farm working; 2 full-time off-farm working)	0.99	0.99
region	Location of the family (1: northern region with pasta as staple food; 2: southern region with rice as staple food)	1.54	0.50
urban	Type of the family (1: urban family; 2: rural family)	1.66	0.47

Table 2 Household Food Consumption and Waste in 1991, 2000 and 2009

Food consumption and waste[1]	1991	2000	2009
Food consumption at home[2] (g)	14,330	11,125	8,200
Food waste at home (g)	501.5	472.5	266.6
Percentage of households having food waste (%)	56.4	58.1	64.9

Notes: [1] The values represent the total weight of food consumed and wasted at home over three days in the surveyed nine provinces; [2] Food consumption is derived from summing the initial amount of food on hand prior survey and the amount of food purchased or self-supplied over the survey, subtracting the amount of food waste over survey period and the food remaining at the home after survey.

Table 3 Household food consumption and waste: provinces-level and Urban/Rural-level

province	Food consumption (g)			Food waste (g)			Percentage of Household that have food waste (%)		
	1991	2000	2009	1991	2000	2009	1991	2000	2009
Liaoning	10385	10005.6	8157.5	266	287.7	219.8	37.9	41.39	58.7
Heilongjiang	--	10434.1	7822.5	--	212.3	133.9	--	42.01	39.5
Jiangsu	13305	11609.1	9042.5	626.5	453.6	209.1	55.0	61.49	56.5
Shandong	11180	10809.0	8500.7	494	302.8	259.1	60.9	43.57	78.1
Henan	11760	15258.8	8548	500	691.7	266.7	51.2	57.11	63.3
Hubei	14030	11092.4	7385.9	689	675.9	461.4	73.1	78.79	82.3
Hunan	11070	10123.9	7604.7	367.5	550.5	256.4	46.3	61.92	64.8
Guangxi	12275	11031.0	8894.8	601	625.1	329.2	54.1	66.81	72.2
Guizhou	29710	9987.2	7807	458	439.8	273.7	70.4	67.77	70.8
Urban	13995	10670.4	8355.1	403	395.7	238.8	56.3	58.71	62.5
Rural	14490	11349.4	8125.8	547.5	510.2	279.8	56.4	57.87	66.1

Note: The Heilongjiang Province is firstly surveyed at 2000, so its value missed in 1991.

Table 4 Total size of household food waste in China

food waste	1991	2000	2009
Annual amount per capita (kg)	15.91	16.74	10.76
National-wide total size (Million tons)	18.433	21.213	14.356

Note: The national-wide total size of household food waste = the annual amount per capita × total population.

Table 5 The Tobit And Double Hurdle Model Results Of Household Food Waste

Variable	(1) The Tobit model			(2) The Double Hurdle model					
	1991	2000	2009	1991	1991	2000	2000	2009	2009
	wasteamt			ifwaste	wasteamt	ifwaste	wasteamt	ifwaste	wasteamt
hage	-4.787	-5.808	-11.927***	-0.006	0.007	-0.013	0.004	-0.012	-0.030***
	[5.386]	[4.610]	[3.318]	[0.008]	[0.008]	[0.007]	[0.007]	[0.008]	[0.008]
hedu=1	83.001	-2.163	-31.181	0.094	0.060	-0.060	0.031	-0.121	0.004
	[49.666]	[50.055]	[33.795]	[0.070]	[0.069]	[0.076]	[0.074]	[0.080]	[0.082]
hedu=2	56.226	-8.006	-55.156	0.099	0.018	-0.050	0.031	-0.222**	0.039
	[54.737]	[53.061]	[33.806]	[0.077]	[0.077]	[0.080]	[0.079]	[0.079]	[0.083]
hedu=3	63.866	-24.308	-37.627	0.083	0.037	-0.076	0.004	-0.154	-0.028
	[65.319]	[60.393]	[38.373]	[0.092]	[0.091]	[0.091]	[0.091]	[0.090]	[0.095]
hifwork=1	9.333	56.573	-18.581	-0.037	0.130	0.079	-0.012	-0.003	-0.112
	[69.228]	[49.399]	[27.208]	[0.099]	[0.095]	[0.072]	[0.076]	[0.063]	[0.068]
fage	-1.205	3.163	9.561**	0.001	-0.013	0.006	-0.007	0.009	0.020*
	[5.544]	[4.659]	[3.348]	[0.008]	[0.008]	[0.007]	[0.007]	[0.008]	[0.008]
fedu=1	-107.141*	-50.416	-4.393	-0.201**	-0.011	-0.108	0.026	-0.014	-0.078
	[49.424]	[44.307]	[30.465]	[0.069]	[0.070]	[0.067]	[0.066]	[0.071]	[0.075]
fedu=2	-71.053	-99.515*	-18.906	-0.119	-0.084	-0.194**	0.055	0.059	-0.196*
	[55.440]	[50.052]	[31.410]	[0.078]	[0.077]	[0.075]	[0.076]	[0.073]	[0.078]
fedu=3	-213.698**	-120.718	-54.239	-0.321**	-0.068	-0.238**	0.030	-0.177*	-0.109
	[72.839]	[62.024]	[37.967]	[0.101]	[0.102]	[0.092]	[0.094]	[0.086]	[0.097]
ffulwork=1	-257.210***	152.500***	50.122	-0.401***	-0.038	0.124	0.241***	0.596***	-0.373**
	[61.374]	[46.252]	[62.419]	[0.089]	[0.083]	[0.068]	[0.071]	[0.171]	[0.144]
ffulwork=2	-194.260**	-33.137	28.236	-0.233*	-0.166	-0.077	-0.056	0.002	0.130*
	[65.723]	[52.159]	[24.561]	[0.095]	[0.089]	[0.076]	[0.080]	[0.056]	[0.062]
lhincg	24.814	37.326*	28.249**	0.033	0.013	0.056*	0.008	0.026	0.106***

	[25.800]	[17.135]	[9.918]	[0.033]	[0.037]	[0.024]	[0.026]	[0.022]	[0.025]
hhsize	40.880*	34.360*	37.602***	--	0.049*	--	0.108***	--	0.062**
	[16.161]	[14.390]	[8.027]	--	[0.023]	--	[0.021]	--	[0.020]
youthnum	-41.151	58.754*	-2.045	--	-0.066*	--	0.017	--	-0.041
	[22.961]	[22.957]	[16.538]	--	[0.032]	--	[0.034]	--	[0.041]
region=2	245.342***	371.406***	123.511***	0.302***	0.157**	0.552***	0.180***	0.283***	0.240***
	[35.474]	[31.181]	[19.861]	[0.049]	[0.051]	[0.045]	[0.048]	[0.045]	[0.050]
t2=2	46.353	-42.426	34.062	0.046	-0.006	-0.120*	0.085	0.052	0.070
	[38.511]	[34.069]	[21.900]	[0.054]	[0.054]	[0.051]	[0.052]	[0.050]	[0.056]
cons	42.522	-504.279**	-161.715	0.175	6.047***	-0.187	5.393***	0.248	4.746***
	[236.475]	[190.026]	[121.031]	[0.313]	[0.337]	[0.273]	[0.290]	[0.276]	[0.305]
lnsigma cons	--	--	--	--	-0.064***	--	-0.031	--	0.122***
	--	--	--	--	[0.017]	--	[0.016]	--	[0.015]
LR Chi^2	91.15***	304.52***	144.93***		121.66***		374.65***		216.32***
pseudo R^2	0.003	0.009	0.004		0.005		0.012		0.007
N	2972	3413	3530		2972		3413		3530

Note: (1) The values in brackets are standard error; (2) * significant at the 10% level, ** significant at the 5% level, *** significant at the 1% level.