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Will healthy diets increase household food waste?

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With rapid changes in Chinese society, people's health awareness is also increasing fast, and diets have transitioned from the pursuit of "filling up" to "being well-fed" to today's "eating reasonably and healthily." How does this change in healthy diet awareness affect household food waste? Based on a theoretical analysis of the relationship between healthy eating awareness and household food waste, this study uses data from the China Health and Nutritional Survey (CHNS) to further investigate the issue. This study is the first to view household food waste from the perspective of healthy diet awareness and propose a theoretical framework of the effects of healthy diet awareness. The results show that greater awareness of what constitutes a healthy diet can significantly reduce household food waste. Household size, family population structure, income, and the employment status of the household's main female member are important explanatory variables. We believe government support for advocating and publicizing healthy diets will help reduce household food waste.

KEYWORDS

household food waste, healthy diet awareness, Chinese households, tobit with instrumental variable, extend regression model

1. Introduction

The level of global annual food loss and waste is shocking.¹ A report from the Food and Agriculture Organization shows that approximately 1.3 billion tons of food are lost or wasted around the world every year, accounting for about 32% of food production worldwide (FAO, 2011). Such a large amount of food loss and waste each year directly reduces the actual global food supply, contributes towards increases in global food prices, and aggravates the food crisis in developing countries. Furthermore, it also indirectly increases greenhouse gas emissions and the inefficient utilization of water and land resources, thereby aggravating ecological tensions (Gustavsson et al., 2011; Quested et al., 2013). In particular, household food waste from at-home consumption represents a major component of the total amount lost each year: over 50% in

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). "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 during the production, storage, processing, and distribution phases of the FSC, and it 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 suitable quality for human consumption but 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 of the FSC and is the result of negligence or a conscious decision to throw food away (Lipinski et al., 2013).

Europe (Quested et al., 2011; Kummu et al., 2012) and over 60% in the United States (Griffin et al., 2009).

In China, with economic development and improvements in living standards, food waste has become increasingly widespread, causing serious concern for society and becoming an important theme in the media. With strong support from the Chinese government, the “Empty Plate” campaign was launched in 2013, and has since become an important social initiative to reduce food waste. Despite the intense public concern, Chinese scholars who study food waste are still few in number. Although it is difficult to get a glimpse of a complete and accurate picture of the scale of food waste in China from existing studies, a survey conducted from 2013 to 2015 showed that the amount of food wasted in urban areas in the catering sector reached 17–18 million tons. This amount could have supported the survival of 30–50 million people on an annual basis (Sun et al., 2018).

For household food waste² in China, some studies found its proportion to be declining slowly over time and even stabilizing in recent years, which is opposite to the increasing trends seen in the U.S. and Europe (Jiang et al., 2018). However, the *per capita* amount cannot be ignored. For example, Song et al. (2015) found that the household food waste *per capita* could reach up to 16 kg/year. Figures estimated by Jiang et al. (2018) are less than the former, but could be at least 7.63–10.86 kg/year. According to this more conservative estimate, the yearly total household food waste in China is at least 10.56–15.02 million tons. Therefore, China needs to urgently take effective measures to curb, and even significantly reduce, household food waste to implement the public goal of “advocating economic saving and opposing extravagance and waste.” In order to establish which measures will prove to be more effective and more in line with China’s realities, we need to first understand the causes of household food waste and then explore the behavioral mechanisms of households with respect to food waste and identify the important determinants behind them.

The causes of household food waste can be summarized as four situations: over-purchasing, impulsive buying or unreasonable purchasing of food under limited rationality and incomplete information; inappropriate storage or management of food or food material at home; inappropriate cooking methods; and excessive preparation of food combined with a lack of knowledge of how to effectively use residual food to prepare other food items (WRAP, 2008, 2009). For these types of food waste, scholars believe that they are usually closely related to the family members’ habits, preferences, attitudes, cognition, and other behaviors (Lipinski et al., 2013). Several variables that influence individuals’ decision making have been proven to be important factors in household food waste: family size and population structure (Parfitt et al., 2010; Song et al., 2015), household economic status (Schneider, 2008; Jiang et al., 2018), members’ demographic and employment characteristics (Schneider

and Obersteiner 2007; WRAP, 2008; Jiang et al., 2018), and socio-cultural background (Timmermans et al., 2014).

However, in combing these studies, we found that, although people’s awareness and attitudes were mentioned (Lipinski et al., 2013), few works paid particular attention to their effects from both a theoretical and empirical perspective. Awareness of and attitudes on environmental protection and resource conservation in the food waste problem discussion are important to highlight, but the impact of the significant changes in people’s health awareness and attitudes in recent years is equally worth investigation. Regarding diet, the pursuit of Chinese people has sharply shifted from “filling up” and then “being well-fed” to today’s “eating reasonably and healthily” (Wang et al., 2017). With more people in the pursuit of healthy diets, it is necessary to study how and why household food wastes may differ with the emerging awareness of what constitutes a healthy diet.

Regarding the relationship between healthy eating and food waste, we found only two studies on this subject in the literature. In both studies, researchers state that healthy diets require a large proportion of fresh fruits and vegetables in their food structure. The relative difficulty of storing fruits and vegetables and the freshness requirement of food ingredients in healthy eating can easily induce more discarding of food in household consumption because of improper food storage management and cooking (Conrad et al., 2018). In addition, by-products with a lower health index (such as high-fat dairy products) will not be consumed by healthy diet adherents, and therefore, are more likely to be discarded (Macdiarmid et al., 2012). This creates more food waste in households seeking to maintain a healthy diet. If the conclusions above are generally established, advocates of healthy diets will inevitably contradict the idea of environmental protection as a reason to reduce food waste.

Therefore, empirical evidence is required to confirm whether a healthy diet causes an increase in food waste. The answer to this question is related to the common realization of healthy diet implementation, resource conservation, and environmental protection. To this end, based on the theoretical analysis of the relationship between healthy diet awareness and household food waste, we used the China Health and Nutritional Survey data (CHNS) to verify their relationship. The remainder of this paper is organized as follows. Section 2 presents the theoretical framework and regression models. Section 3 lists the data source and sample description. Section 4 reports and discusses the empirical results, and Section 5 provides the conclusions and implications for policy.

2. Theoretical framework and regression models

2.1. Theoretical framework

In families, the level of awareness of healthy diet and its relationship with food consumption and waste are reflected mainly in the behaviors of members responsible for food purchase and food production. In China, these members are usually the same individual, the spouse of the male household head or the female household head (i.e., the main female member). Therefore, in this paper, we use this main female member’s healthy diet awareness to express the overall level of the household’s healthy diet awareness.

² In the definition from the FAO (2011), food waste refers to the food thrown away in the final consumption. According to the location of food waste, it can be divided into food waste in the home (called it as “household food waste”) and food waste outside the home such as waste in eateries or staff canteens (called “catering food waste”). In this paper, we use the FAO (2011) definition to define household food waste.

We believe that the effects of increased dietary awareness on household food waste are both reducing and increasing in nature. The effects of healthy diet awareness on household food waste are summarized as the following six aspects. First, families with a strong awareness of healthy diets will reduce food waste through more rational planning of food purchases. The frequency and quantity of ingredients purchased can affect food waste. Because of the lower purchase frequency and greater amount of purchase at a single event, food ingredients cannot be consumed in a timely manner, are forgotten about, and then get spoiled or expire, creating food waste (Quested et al., 2013). Families with high healthy diet awareness usually pay more attention to the freshness and quality of ingredients, which may make these families form purchase patterns based on higher frequency for lesser amounts and thereby have less food waste.

Second, the promotion of healthy diet awareness will reduce food waste by promoting household learning for food preservation knowledge and improvements in storage facilities. Household food storage equipment, technology, and knowledge can affect food waste (Quested et al., 2013). Pursuing a healthy diet will require families to improve food storage conditions and technology to reduce food waste. Third, the enhancement of awareness of a healthy diet would increase dietary diversity and subsequently reduce food waste. Balanced nutrient intake is an important dimension of a healthy diet. In order to ensure a balanced diet, this requires a diversified mix of foods, which reduces the time spent on cooking each type of food, and avoids food waste caused by improper cooking and taste.

Fourth, the increase in healthy diet awareness will reduce the amount of food waste due to price effects. In reality, the price of ingredients is an important factor affecting household food waste. Generally, lower-priced foods are more likely to be discarded. For higher-priced foods, the possibility of waste is relatively low. Ingredients of healthy diets are generally of good quality and high in nutritional value. As the price of these ingredients is relatively high, this will increase the cost of food waste; thus, healthy eating would reduce the amount of household waste for these healthy foods.

Fifth, improvement in healthy diet awareness will increase the amount of household food waste due to the increase in the proportion of fruits and vegetables consumed. In general, a healthy diet has a higher proportion of fruit and vegetables. Fruit and vegetable ingredients are more prone to spoilage due to difficulty in preservation, which may result in more food waste generation in the household (Conrad et al.,

2018). In addition, the increased dietary diversity brought about by healthy eating may increase the possibility of waste considering the variety of ingredients. Sixth, improvement in healthy diet awareness will also reduce the frequency of dining out and increase the probability of eating at home, thus increasing the possibility of household food waste generation. Generally, people in China believe that eating out is not good for health; thus, healthy eating will increase the frequency of meals at home and, in turn, the probability and quantity of food waste. However, it should be noted that reducing the frequency of eating out will also reduce food waste in eateries, and the impact on the total amount of food waste remains uncertain.

Based on the six points above, the reduction effects may be stronger than the increasing effects. Therefore, we believe that an increase in healthy diet awareness will theoretically reduce household food waste. However, this requires the support of empirical research. In addition to healthy diet awareness, we introduce three other categories of factors into the empirical analysis of household food waste in China: individual characteristics (e.g., age, education level, and employment), family characteristics (e.g., family size, number of children and youths in the family, and family economic status), and contextual characteristics (e.g., regional location and Hukou type of the families). The theoretical framework is shown in Figure 1.

2.2. Regression model

According to the analytical framework, we establish the following econometric model to estimate the effects of healthy diets on household food waste:

$$fwaste_i = f(hdiet_i, X_i^{IC}, X_i^{FC}, X_i^{RC}, \varepsilon_i) \tag{1}$$

In Eq. (1), *fwaste* is the household food waste, *hdiet* is the healthy diet awareness, *X^{IC}*, *X^{FC}* and *X^{RC}* are the independent variables of individual characteristics, family characteristics, and contextual characteristics, respectively, and μ is the random disturbance term.

For whether family members have healthy diet awareness, we consider that he or she firstly needs to have full dietary knowledge to know what kind of diet is healthy and reasonable. Secondly, on the

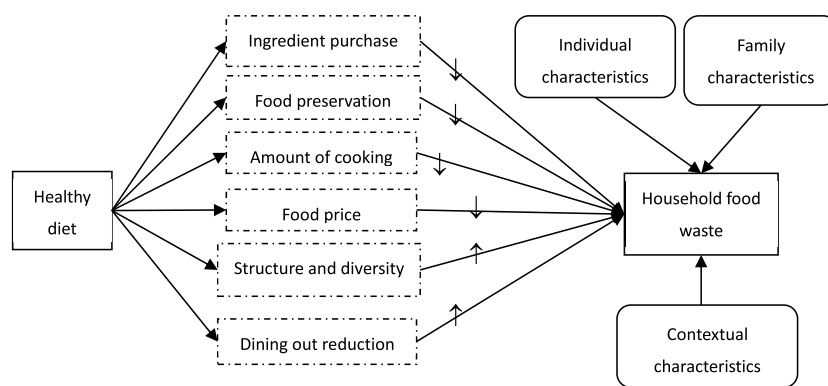


FIGURE 1
Effects of healthy diets on household food waste.

basis of their understanding of a healthy diet, individuals must focus on dietary health and have healthy eating behaviors in their daily lives. With this judgment of healthy diet awareness, combined with the survey questions in the CHNS data, we use individuals' answers on "Do you know about the Chinese dietary pagoda or Chinese Dietary Guidelines?" to judge whether they have full knowledge of healthy diets. Then, according to their choices in the question, "How important is eating a healthy diet as a priority in your life?" to indicate whether they indeed care about the health of their daily diet (i.e., the awareness of the importance of healthy diet). Therefore, in the variable quantification, we use the knowledge of healthy diet (*hdiet_inf*), the awareness of the importance of healthy diet in daily life (*hdiet_imp*), and their interaction (*hdiet_int*) to indicate the main female member's healthy diet awareness as a whole. In the regression, we progressively introduce these three variables into Eq. (1) and use the estimated coefficients of these three variables and their changes to illustrate the effects of healthy diet awareness on household food waste.

Since a considerable fraction of households generates no food waste, this leads to the dependent variable *fwaste* having a large number of zero values, that is, a corner solution problem is in the regression. For models with corner solutions, we are not only interested in the discrete part of the dependent variable's distribution that generates the zero observations, but also in the continuous part that generates the positive observations (Pudney, 1989). Thus, the Tobit model or the Hurdle model is generally used for regression estimation. In light of the likelihood that the choice whether to waste and the choice of how much waste are in a single behavioral mechanism, we use the Tobit method to estimate Eq. (1). Meanwhile, because the household healthy diet awareness and food waste behaviors may be affected by some unobservable factors (e.g., preferences, cultural traditions, etc.), there is an endogeneity problem of simultaneous errors in this estimation. Therefore, we will first search the instrumental variable for healthy diet awareness, and then apply the IV-Tobit method to re-estimate and use the extended regression model (ERM) to further test the robustness of the results (Finlay and Magnusson, 2009).

In the model in Eq. (1), we use the total amount of food waste for three consecutive days in the family to indicate household food waste. As mentioned above, we use the main female member's knowledge of healthy diet, her awareness of the importance of a healthy diet in daily life, and the interaction between knowledge and importance to indicate the healthy diet awareness of the family. The individual characteristic variables are age (*age*), education level (*fedu*), and employment status (*fifwork*); the household characteristics variables are family size (*hsize*), number of children and youth in the family (*youthn*), and family economic status (*lhincg*); the contextual characteristic variables are the Hukou type of the family (*urban*) and regional location (*region*). In addition, to control the time trend of food waste, we added time dummy variables (*waves*).

3. Data source and sample description

3.1. Data source

Data for this paper was taken 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 CHNS wave was conducted in 1989; since then, it has been repeated every two or three years. The survey data in waves from 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, and 2011 were available from the survey's official website.

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 based on a 24h recall method. In this method, investigators would inquire about the detailed dietary intake of the respondents' household in the 24h prior to the survey, and obtain the food consumption and waste data by weighing the initial amount on hand, purchased or self-supplied amount, wasted amount, and remaining amounts. Given the various types of food eaten every day in Chinese households and even greater differences in dietary structures among Chinese families, this dietary survey would be repeated after three days to reduce sampling errors. Since the food consumption and waste data in 1989 was incomplete, the questions of healthy diet knowledge and the importance of healthy diet were added for the first time in 2004, and only consumption and waste data for edible oil and spices have been collected since 2011, our empirical analysis is mainly based on the waves of 2004, 2006, and 2009. We have combined these three rounds of data into a set of pooled cross-section data.

Before using this data for statistical description and econometric estimation, we clean the data as follows. First, we exclude the household observations that have missing values in key variables such as food consumption and waste. Then, we remove the households for which the three-day food consumption amount is less than 0g or the three-day waste amount is larger than 2,500g in order to reduce the impact of data outliers on the regression results. After the data cleaning, the number of valid households in this data set is 8,449 (see Table 1).

3.2. Sample description

From the statistical results in Table 2, the three-day average household food waste was 341.564g. In all families, a limited number of the main female members knows the Chinese dietary pagoda or Chinese Dietary Guidelines, accounting for only 10.8% of the whole sample. Most of them do not really understand what a healthy diet is and do not have full knowledge of them. They believe that eating a healthy diet is an important priority in their daily lives and exhibit behaviors to reflect that. The majority of the main female members in the sample (94.2%) consider that adhering to a healthy diet in daily life is important. The results from the interaction of dietary knowledge and the importance of healthy eating show that the main female members have knowledge of healthy diets, and almost all agree that healthy eating is important. The proportion of these members who fully understand healthy diets and believe that healthy diets are important is 10.6%, the same as the proportion of families who know the Chinese dietary pagoda. Because of this fact, the introduction of this interaction may bring a serious collinearity problem in the regression. Therefore, we intend only to include the interaction in the baseline regressions at a later stage, and the introduction of the interaction term in other regressions will be determined from the estimated results of the baseline regression.

In terms of individual characteristics, the average age of the main female members is 50 years old, their average education level

TABLE 1 Variable definition and value description.

Variable	Definition	Variable interpretation and value description
fwaste	Household food waste	Total amount of food discard for 3 consecutive days in the family
hdiet_inf	Knowledge of healthy diet	Knowledge about the Chinese dietary pagoda or Chinese Dietary Guidelines: 0 if participant does not know, 1 if he/she knows
hdiet_imp	Importance of healthy diet in daily life	Importance of a healthy diet in life: 0 if participant considers unimportant, 1 if important
hdiet_int	Interaction of the variable hdiet_inf and hdiet_imp	
fage	Age of main female member	
fedu	Education level of main female member	The highest education degree: 0 if illiterate, 1 if elementary school, 2 if junior high school, 3 if high school, 4 if secondary school, 5 if college or university, 6 if Master's and above
fifwork	Employment of main female member	Currently working: 0 if no, 1 if yes
hsize	Family size	Number of family members at home
youthn	Number of children and youth at home	Number of members under the age of 17 at home
lhincg	Family's economic status	The logarithm of household total net income
Urban	Hukou type of the family	Hukou type: 1 if urban household, 2 if rural household
Region	Regional location of the family	Region: 1 if western, 2 if northeastern, 3 if central, 4 if eastern
Wave	Year	

(a) As far as the concept is concerned, the statistical caliber of discarded food is greater than food waste, because discarded food includes a reasonable portion of food items that cannot be cooked or eaten. However, in the survey of food waste, it is impossible to accurately distinguish the reasonable part from the unreasonable part. Therefore, researchers usually use the amount of discarded food to approximate the amount of food waste (WRAP, 2008; Song et al., 2015). In this paper, we also use discarded food to indicate food waste. (b) In the original source, the importance factor has five scale values: 1 = not important at all, 2 = not very important, 3 = important, 4 = very important, 5 = the most important. In this variable generation, we have done a dimensionality reduction on the scale and divided the importance into two dimensions: unimportant and important.

TABLE 2 Descriptive statistics of the sample.

Variable	Pool data		2004		2006		2009	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
fwaste	341.564	571.014	408.974	677.964	306.193	499.063	285.173	405.552
hdiet_inf	0.108	0.311	0.069	0.254	0.119	0.324	0.134	0.340
hdiet_imp	0.942	0.234	0.915	0.279	0.958	0.200	0.950	0.219
hdiet_int	0.106	0.308	0.066	0.248	0.117	0.322	0.132	0.338
fage	49.892	11.001	48.247	11.018	49.814	10.871	51.443	10.890
fedu	1.538	1.330	1.533	1.282	1.539	1.367	1.540	1.338
fifwork	0.535	0.499	0.539	0.499	0.543	0.498	0.526	0.499
hsize	3.462	1.351	3.455	1.226	3.484	1.373	3.448	1.434
lhincg	9.877	1.007	9.607	0.949	9.769	0.976	10.222	0.990
youthn	0.525	0.720	0.578	0.712	0.511	0.716	0.492	0.728
Urban	1.646	0.478	1.643	0.479	1.646	0.478	1.649	0.477
Region	2.568	1.048	2.566	1.039	2.569	1.045	2.568	1.059

For binary variables with values of 0 and 1, the mean is essentially the proportion with a value of 1.

is junior high school, and 53.5% are currently employed outside the home. With respect to family characteristics, the average number of family members in the home is 3.462, the average number of children at home under 17 years old is 0.525, and the average logarithm of household total net income is 9.887 (approximately 301,414.6 Yuan). Over time, the amount of food waste in the family is declining; the number of households whose main female member has knowledge of the dietary pagoda is expanding, and the number of families who believe that healthy eating is also increasing,

indicating that the healthy diet awareness of Chinese families is growing.

In Figure 2, we further illustrate the relationship between healthy diet awareness and household food waste. The average three-day food waste amount in the families whose main female member does not have healthy diet knowledge was 348.4g, while that of the families whose main female member has healthy diet knowledge was 285.279g, a difference of 63.2g. From the perspective of awareness of the importance of healthy diet, the average amount of food wasted in



FIGURE 2
The relationship of healthy diet awareness and household food waste.

three days was 453 g in the family group that considered healthy dieting unimportant, while in the group that considered it important, the amount of waste was 334.659 g, which was nearly 119 g lower than the former. Finally, from the results of the interaction term, compared with those families in the opposing group, the food waste is significantly lower among families whose main female has healthy diet knowledge and considers a healthy diet to be important. In conjunction with the statistical description above, we find that households focusing on healthy diets generate less food waste; this seems to validate the hypothesis presented in the framework.

4. Empirical results

4.1. Benchmark estimation: Tobit regression

We first estimate Eq.1 with the Tobit model and use its results as the benchmark (Table 3). In the estimation, we introduce into the model healthy diet knowledge, awareness of the importance of healthy eating, and their interaction, step-by-step. In the first regression with healthy diet knowledge only, it does not pass the significance test. After adding awareness of the importance of healthy eating, we found that healthy eating knowledge is still insignificant, but awareness of the importance of healthy eating passes the test at the significance level of 0.1%. When adding the interaction term, we found this interaction does not pass the test of significance, and the significance and effects of the former two variables are consistent with previous results. Moreover, the values of LR Chi² and log likelihood in column 3 from the regression with the interaction term are almost the same as their values in column 2 without it. Combined with the statistical description of this interaction term, we exclude this term from the subsequent estimations. From these regression results, we consider that the increase in food waste in Chinese families is unaffected by the healthy diet knowledge of the family, but is strongly negatively related with the awareness of the importance of healthy diets, regardless of the existence of healthy diet knowledge. These regression results also indicate that Chinese families display a high level of health awareness in their diets, but a poor understanding of scientific dietary knowledge, such as the Chinese dietary pagoda (or dietary guidelines).

The coefficient of the awareness of the importance of healthy eating in column 2 of Table 3 is -169 . This means that, compared with the families that do not believe in the importance of healthy diets, the food waste over three days is 169 g less in families that consider healthy diets important. This declining effect is obvious. This result

provides empirical evidence for the hypothesis presented earlier. This also proves that a healthy diet is not only beneficial for physical health, but can also reduce food waste and help avoid negative externalities caused by food waste.

The results of other controlled variables highlighted several points. (1) Household food waste decreased significantly over time. This may be due to the widespread use of the refrigerator in Chinese families or the popularity of eating outside the home in China. (2) The regional differences in household food waste generation are obvious, and are possibly associated with regional differences in the dietary culture and structure. (3) The household food waste generated in rural families is higher than that in urban families. This may be due to rural–urban differences in food purchasing behaviors, food preservation abilities, or degree of self-supply of food ingredients. (4) Families with a more members younger than 17 years old have a higher total amount of household food waste. This may be related with the high uncertainty of the dietary habits of children. (5) The more family members at home, the greater the amount of food waste in the families. (6) In families where the main female is working, the level of household food waste is higher than in families where the main female is unemployed. (7) Families with higher total net income produce more household food waste.

4.2. Endogenous discussion and the IV-Tobit regression

In these regressions, the family's healthy diet awareness, especially the importance of the awareness of healthy diets, may be endogenous. This endogeneity may originate from two sources. First, some unobserved factors, like family culture and customs, will simultaneously affect healthy diet awareness and household food waste in families. Second, healthy diet and household food waste may affect each other. Both may bring estimation bias. The identification of instrumental variables is an effective method for solving endogeneity issues. However, no study has determined the instrumental variables for healthy diets. This article is the first to explore this issue.

We selected the occupational position of the spouse of the household's main female member as the instrumental variable for the following reason. In China, the major decision makers in the purchase of ingredients and cooking behaviors in families are females, and direct effects of male individual characteristics on household food waste are relatively weak. The occupational position characteristics of a male member may affect his spouse's healthy diet awareness. For example,

TABLE 3 The benchmark regression: Tobit regression.

Variable	(1)	(2)	(3)
hdiet_inf = 1	-10.19 (30.78)	-7.458 (30.76)	-181.2 (190.0)
hdiet_imp = 1		-169.0*** (37.21)	-175.7*** (37.92)
hdiet_int = 1			178.2 (192.3)
fage	-0.151 (1.032)	-0.0623 (1.031)	-0.0762 (1.031)
fedu = 1	-43.10 (26.16)	-42.58 (26.15)	-42.60 (26.14)
fedu = 2	-30.99 (26.79)	-26.81 (26.79)	-26.83 (26.79)
fedu = 3	-69.09* (34.48)	-62.66 (34.49)	-62.66 (34.49)
fedu = 4	-15.21 (43.81)	-5.967 (43.82)	-6.698 (43.83)
fedu = 5	-84.61 (59.40)	-76.78 (59.38)	-77.64 (59.39)
fedu = 6	524.4 (764.9)	534.3 (764.3)	535.2 (764.2)
fifwork = 1	61.24** (20.15)	59.16** (20.14)	58.72** (20.15)
hsize	43.89*** (8.242)	43.21*** (8.238)	43.27*** (8.237)
lhincg	37.96*** (9.819)	39.08*** (9.817)	38.97*** (9.816)
youthn	21.94 (15.52)	22.01 (15.51)	21.99 (15.51)
Urban = 2	95.18*** (20.46)	93.17*** (20.45)	93.20*** (20.45)
Region = 2	-71.07* (28.09)	-68.25* (28.08)	-68.73* (28.08)
Region = 3	105.7*** (25.60)	104.6*** (25.59)	104.0*** (25.59)
Region = 4	-67.48* (28.06)	-67.14* (28.04)	-67.54* (28.04)
Wave = 2006	-151.6*** (22.34)	-144.5*** (22.38)	-144.6*** (22.37)
Wave = 2009	-140.0*** (22.83)	-135.2*** (22.84)	-135.2*** (22.84)
Cons	-353.3** (114.9)	-212.9 (118.9)	-204.2 (119.3)
LR chi ²	284.05***	304.63***	305.49***
Pseudo R ²	0.003	0.003	0.003

(1) Standard errors are in parentheses; (2) ***, **, and * indicate the significance levels of 0.1%, 1%, and 5%, respectively.

consider a family in which the spouse of the main female member is an employer and dines out frequently for business social activities; thus, his wife may pay more attention to ensuring a healthy diet when he eats at home, and the dietary structure will tend to be bland. Additionally, the occupational position of the spouse may be strongly correlated to the number of times the family dines at home, and thus affect household food waste. In the CHNS data, this variable was extracted from the question “What is your occupational position?”

The results of the Wald test of exogeneity (in Table 4) showed that endogeneity was significantly present in this regression. The robust tests of the instrumental variables showed that the occupational position of the spouse of the main female member as an instrumental variable for healthy diet awareness is reasonable. From the estimation results of the IV-Tobit regression, we can see that the significance and effect of healthy diet knowledge and the awareness of the importance of healthy diets are consistent with the results in the benchmark Tobit regression. The estimation results for the other control variables were also similar and, therefore, not discussed here.

4.3. Robustness test of results with ERM regression

The exogeneity and robustness tests of the instrumental variable proved the endogeneity of healthy diet awareness and the feasibility of the instrumental variable we adopted. However, in the IV-Tobit model, the endogenous variable must be a continuous variable. Therefore, new models are required to solve the estimation problem of the endogenous variable as a binary discrete variable in the standard Tobit regression. The ERM regression is used to address this problem (Angrist, 2001; Cameron and Trivedi, 2010; Roodman, 2011). To this end, we have used the ERM regression to make a re-estimation for the robustness test.

From the estimation results in Table 4, the *p*-value indicating the correlation of the residual terms in the equation of household food waste and healthy diet awareness (the corr (e.hdiet_imp, e.fwaste) in Table 4) is significant at the 1% level, implying that the ERM is reasonable and suitable and that healthy diet awareness is indeed an endogenous variable. This confirms the results of the IV-Tobit model. Comparing the results of ERM, IV-Tobit, and the standard Tobit regression, we observe that the variables that have a significant explanatory effect on household food waste are the same in all three regressions. This shows that the results are robust. From the ERM estimation results, we see that the food waste amount of households that consider healthy diets important will fall by 974.1 g, with an average daily amount of 324.7 g. This further verifies the hypothesis.

5. Conclusions and implications

Although the volume of Chinese household food waste declined during the 1991–2009 period due to the increase of out-of-home dining, the percentage of households that have food waste is on the rise (Jiang et al., 2018), and the *per capita* amount of Chinese household food waste is very serious. Therefore, it is still of great practical significance to explore the decision mechanisms of household food waste and find out the determinants that explain the amount of food waste in the family. However, due to the rapid social changes in China, the public's health awareness is also increasing at a

TABLE 4 The results of IV-Tobit regression and ERM regression.

Variables	IV-Tobit	ERM
hdiet_inf = 1	36.38 (45.95)	-15.03 (21.00)
hdiet_imp = 1	-3046.56* (1418.47)	-974.1*** (26.46)
fage	1.600 (1.498)	0.368 (0.735)
fedu = 1	-30.88 (34.68)	-34.19 (17.64)
fedu = 2	39.29 (47.70)	-27.16 (18.20)
fedu = 3	42.50 (66.89)	-34.46 (23.46)
fedu = 4	141.9 (92.75)	15.17 (30.11)
fedu = 5	45.68 (98.81)	-35.07 (40.51)
fedu = 6	689.2 (1015.1)	342.5 (581.5)
fifwork = 1	36.13 (31.45)	40.99** (13.81)
hsize	30.99* (12.09)	26.81*** (5.503)
lhincg	52.39*** (14.54)	33.56*** (6.672)
youthn	25.62 (20.27)	21.55* (10.40)
Urban = 2	63.46* (29.57)	44.42** (13.77)
Region = 2	-13.00 (43.44)	-14.59 (19.07)
Region = 3	79.67* (36.00)	93.59*** (17.15)
Region = 4	-54.98 (36.53)	-41.41* (18.97)
Wave = 2006	-37.17 (63.98)	-108.1*** (15.15)
Wave = 2009	-64.07 (49.21)	-116.3*** (15.48)
Cons	2237.8 (1221.7)	838.7*** (82.19)
Wald chi ²	178.23***	1771.19***
Wald test of exogeneity	5.88*	
Weak instrument robust test	4.56*	
corr(e.hdiet_imp,e.fwaste)		0.762***

(1) Standard errors are in parentheses; (2) ***, **, and * indicate the significance levels of 0.1%, 1% and 5%, respectively.

fast pace, as reflected in the transition from “filling up” to “eating reasonably and healthily” (Wang et al., 2017). Given the public’s pursuit of healthy diets, this study sought to gain a better understanding of whether the household food waste will differ according to people’s healthy diet awareness and determine the nature of, and rationale behind, such a potential difference.

Based on a theoretical analysis of the relationship between healthy diet awareness and household food waste, this paper has applied CHNS data for an empirical response. The results show that the improvement of healthy diet awareness can significantly reduce household food waste. Beyond awareness, household size, family population structure, income, and whether the main female member is employed are important explanatory variables of household food waste. There are two main contributions of this paper. It is the first attempt to explain household food waste from the view of healthy diet awareness and apply a theoretical framework to the effects of healthy diet awareness. In addition, we found a reasonable instrumental variable for healthy diet awareness and then tested its effect on household food waste with an extended regression model (ERM). According to the findings, advocating and publicizing healthy diets will help reduce household food waste, and the government should strengthen the propagation and popularization of dietary knowledge.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

XC presented the study and critically revised its important elements. XL supervised the data collection, performed the preliminary analysis, and reviewed and revised the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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