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The Impact of Proximity to Wet Markets and Supermarkets on Household Dietary Diversity in Nanjing City, China

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Abstract: This study investigated the influence of the proximity to wet markets and supermarkets on urban household dietary diversity in Nanjing. Based on the data collected through a citywide survey in 2015 and the map data of wet markets and supermarkets, the Poisson regression model was deployed to examine the correlations between geographical proximity to supermarkets and wet markets and household dietary diversity. The result shows that the coefficients for the distance to the nearest wet market are not statistically significant. Although the coefficients for the distance to nearest supermarket are statistically significant, they were too minor to reach a practical importance. We argue, however, that the insignificant correlations reflect exactly the high physical accessibility to food outlets and the extensive spatially dense food supply network constituted by wet markets, supermarkets and small food stores in Nanjing, due in part to the food infrastructure development planning in Nanjing that has ensured relatively equal and convenient access to wet markets or supermarkets for all households. Our findings are verified by the survey data that more than 90% of households purchased fresh food items within their neighborhoods or in walking distance. In addition to the densely distributed food outlets, various other factors contributed to the non-significant influence of the distance to the nearest wet market and supermarket, in particular, the numerous small food stores within or close to residential communities, the prevalence of three-generation extended household structure and the high household income.

Keywords: proximity to food outlets; dietary diversity; food access; food security; food environment; food geographies

1. Introduction

The relationship between household dietary diversity and access to food markets was investigated in several studies. Some suggest that an increase in distance to food markets may decrease dietary diversity and increase food insecurity [1–3]. Restricted access to supermarkets, in particular, can reduce healthy food consumption [4]. In contrast, other studies maintain that there is no causal linkage between access to food markets and dietary diversity. A study in Michigan, USA, for example, found that physical distance to food outlets providing healthy food did not significantly influence fruit and vegetable consumption [5]. Another study suggests that it is the price of food in supermarkets, rather

than the physical distance to market, that most influences the consumption of fruits and vegetables [6]. This implies that the direct cost of food is a much more important factor than indirect factors such as physical distance and travel cost.

Another group of researchers suggest that the potential impact of distance on dietary diversity is mediated by other factors. Even when supermarkets are physically present in low-income urban areas, for example, this does not necessarily improve dietary diversity since they tend to carry a less healthy and diverse range of foods [7]. A study in the US found that an increase in the distance to a supermarket decreases the odds of fruit and vegetable consumption in metropolitan areas but has no impact in non-metropolitan areas [4]. An analysis of data from 21 different African countries found that distance to the nearest road (and therefore transaction costs for food purchase) had a significantly negative impact on fruit and vegetable consumption, but no significant effect on animal source food consumption [8]. The impact of improved locational access to food markets also tends to vary with household income with low-income households benefitting more than wealthier groups [9]. Thus, while distance to food outlets does seem to be an important variable in household food consumption, a consensus has yet to be reached on its influence on household food security [10].

There is a widespread assumption that the one-stop shopping associated with supermarkets is more convenient than multi-stop shopping and therefore more attractive to consumers. However, in practice, food shopping practices are complex and there are interactions and integration between different market outlets [11]. Despite the proliferation of large supermarkets and hypermarkets, the multi-stop shopping model still prevails in much of Asia [12]. Chinese consumers value the freshness of food and prefer to buy small amounts of fresh vegetables on a daily basis rather than storing vegetables for a longer period [13]. The main advantages of wet markets over supermarkets is the freshness and affordability of food, regardless of supermarket penetration [13,14]. Food purchasing is also shaped by the practice of shopping for different foods at different outlets (i.e., cross-platform shopping); for instance, buying perishable food in traditional wet markets and processed food in supermarkets. Multi-stop shopping at different forms of retail outlet means that dietary diversity and household food security cannot be seen as the outcome of distance to a single food purchasing location.

Previous studies have focused on the impact of proximity to supermarkets on food security and have neglected the influence of proximity to wet markets. Moreover, most studies of food security in China have focused on national or regional-level food supply with few studies paying attention to household-level food security in urban areas. Quantitative analysis of the relationship between physical access to food outlets and household dietary diversity of China is absent. To bridge this gap, this study examines the relationship between proximity to wet markets and supermarkets and urban household dietary diversity.

2. Wet Markets and Supermarkets in Nanjing

Despite the proliferation of supermarket chains since the 1990s, wet markets remain the most prevalent food outlet in urban China. They specialize principally in fresh vegetables, fruit, livestock products, aquatic products (such as live fish and shrimp), poultry products, and staple foods (such as rice and other grains and flours). The Chinese government launched a program in the early 2000s, known as *nong gai chao* in Chinese, to convert wet markets into supermarkets in many large cities [15,16]. However, this project failed in many cities including in Nanjing [13] and wet markets remain dominant in fresh food retailing [13,17]. In the city of Dalian, in northeast China, wet markets are the main fresh food source for almost half (49%) of urban households [18]. In Shanghai, they are the source of fresh meat and vegetables for 76% and 59% of households, respectively [19]. Wet markets carry a variety of fresh foods at low cost, providing a price advantage over supermarkets [13].

The study area is Nanjing, the capital city of Jiangsu province located in East China. It has a population of 8.33 million by the end of 2017 [20]. In Nanjing, wet markets have conventionally been the dominant outlet for fresh, unprocessed food. There were 351 wet markets in Nanjing in 2015, equating to about one wet market per 19,100 people on average (excluding rural households) or one

per 23,464 people (including rural households). The overall density of wet markets is one per 2.1 km². In contrast, there are 63 chain supermarkets in Nanjing, operated by eight companies. The major chains include two Chinese chains, Suguo (38 supermarkets) and BHG (8), and two foreign-owned chains, Carrefour (5) and Wal-Mart (5). Figure 1 shows the location of wet markets and supermarkets across Nanjing's 11 districts.

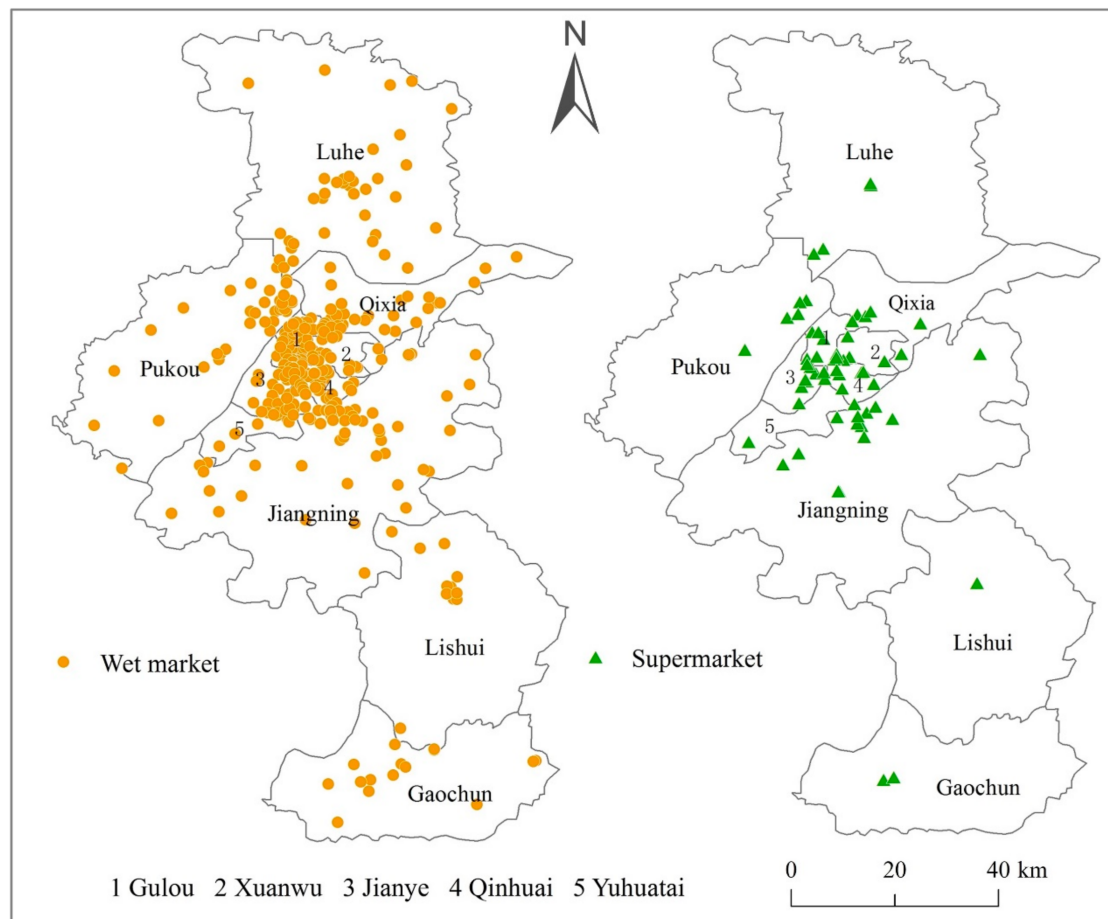


Figure 1. Location of Wet Markets and Supermarkets in Nanjing City. Source: Data from BaiduMap (map.baidu.com).

Nanjing's upgraded wet markets are somewhat different from traditional Chinese wet markets. Traditionally, wet markets were housed in temporary sheds or in the open air. Most wet markets in Nanjing are now housed in permanent buildings and stalls selling meat are usually equipped with refrigeration facilities [13]. Nanjing has had no open air wet market or wet markets in temporary sheds since the end of 2014 [21]. The space of a wet market is usually divided into small stalls which are rented and operated by private individual food vendors.

Wet markets in Nanjing fall under a two-tier management system. The first tier is the Nanjing Municipal Government which owns the city's wet markets and regulates their distribution [22]. The municipal government has supervised the establishment of wet markets to ensure a spatially even distribution by enacting several specific regulations. We elaborate on this policy context in Section 5.1. The second management tier means that wet markets are operated and managed either by state-owned or private companies or offices (hereafter, the management body). The management body is selected by the district-level governments and is responsible for the safety and sanitation of the wet market, stall lease management, facility maintenance and food safety monitoring [22]. The vendors renting the

stalls in wet markets buy food from wholesale markets, distribution centers or other sources and pay a stall rent and fee to the management body.

Supermarkets are another important food source for households in Nanjing. Table 1 shows the distribution of wet markets and supermarkets in each of the 11 districts. It demonstrates that, with only 63 supermarkets selling vegetables and fruit, the number of supermarkets is much smaller than the number of wet markets in every district. Unlike wet markets, there is no statutory requirement for supermarket development by the size of population of an area. The variation of population per wet market across the districts is much smaller than that of supermarket.

Table 1. Wet Markets, Supermarkets and Population in Nanjing.

District	Population	No. of Wet Markets	No. of Super-Markets	Population Per Wet Market	Population Per Supermarket
Xuanwu	652,400	21	6	31,067	108,733
Qinghuai	1,022,400	27	7	37,867	146,057
Jianye	454,500	25	8	18,180	56,813
Gulou	1,275,600	54	6	23,622	212,600
Pukou	749,400	37	6	20,254	124,900
Qixia	679,800	38	7	17,889	97,114
Yuhuatai	426,900	27	3	15,811	142,300
Jiangning	1,191,400	56	14	21,275	85,100
Liuhe	934,400	37	4	25,254	233,600
Lishui	424,400	13	1	32,646	424,400
Gaochun	424,700	16	1	26,544	424,700
Total	8,235,900	278	42	29,626	196,093

Source: Population data from [23].

3. Methodology

3.1. Household Dietary Diversity

The household data used in this paper are extracted from the urban household baseline food security survey in Nanjing conducted in July 2015, and funded by the Hungry City Partnership. The total sample size was 1210 households, randomly selected from 972 urban communities in all 11 districts of Nanjing. The survey was conducted by undergraduate and graduate student enumerators from Nanjing University using digital surveys on android tablets. The data were then uploaded and synthesized on the online Ona database. Household dietary diversity was measured by the Household Dietary Diversity Score (HDDS) [24]. HDDS is a widely used indicator developed by the Food and Nutrition Technical Assistance (FANTA) project [25]. Various studies have proved its relevance and significance in measuring per capita energy consumption. We recognize the critiques on the indicator's accuracy to measure the quality of food access [26], yet it is still a valid indicator to reflect the diversity of household food intake. Food items consumed in the 24 h prior to the survey were grouped into the following 12 food groups: (a) cereals; (b) roots and tubers; (c) vegetables; (d) fruit; (e) meat, poultry and offal; (f) eggs; (g) fish and seafood; (h) pulses, legumes and nuts; (i) milk and milk products; (j) oil and fats; (k) sugar and honey; and (l) other foods. The HDDS is calculated from the number of food groups eaten from and ranges in value from 0 to 12, where the higher the score the greater the diversity in the household diet.

Tables 2 and 3 show the statistical summary of the HDDS in Nanjing and household food consumption by food groups. The dietary diversity of Nanjing households is relatively high with a mean HDDS of 7.83. Some 60% of households scored between 7 and 12 (i.e., eating foodstuffs from between 7 and 12 of the food groups). Over 80% had a score of 6 or more and only 17% had a score of 5 or less. By way of comparison, the mean HDDS of other cities in the Hungry Cities Partnership project was significantly lower (Table 3).

There were notable differences in the frequency of consumption of different food groups (Table 4). Cereals (including wheat, rice and other grains) ranked first with about 98% of households consuming cereals. The vegetable and fruit groups ranked second and third, respectively, with percentages of about 97% and 80%. The roots and tubers group ranked lowest with a proportion of about 34%, slightly lower than fish and seafood at 37%.

Table 2. Frequency Distribution of HDDS in Nanjing.

	No. of Households	%	Cumulative %
1	7	0.6	0.6
2	10	0.8	1.4
3	43	3.6	5.0
4	61	5.0	10.0
5	85	7.0	17.1
6	117	9.7	26.7
7	148	12.3	39.0
8	213	17.6	56.6
9	219	18.1	74.8
10	164	13.6	88.3
11	110	9.1	97.4
12	31	2.6	100.0
Total	1208	100.0	

Table 3. Comparison of HDDS Scores in HCP Cities.

	Household Dietary Diversity Score		
	Mean	% ≤ 5	<i>n</i>
Nanjing	7.83	17.1	1208
Cape Town	6.75	29.3	2504
Nairobi	6.04	40.9	1414
Mexico City	5.85	49.8	1210
Bangalore	5.37	59.1	1878
Kingston	4.51	70.6	698
Maputo	4.14	76.2	2071
Windhoek	3.21	89.1	855

Table 4. Frequency Distribution of Consumption of Food Groups.

Food Item	No. of Households	% of Households
Cereals	1179	97.6
Vegetables	1171	96.9
Fruits	964	79.8
Meat, poultry, offal	952	78.8
Eggs	949	78.6
Oil and fats	937	77.6
Milk and milk products	791	65.5
Pulses, legumes, nuts	539	44.6
Sugar or honey	477	39.5
Fish and seafood	450	37.3
Root and tubers	406	33.6
Other foods	645	53.4

Wet markets and supermarkets are the two most frequently used food sources in Nanjing [27]. Almost 93% and 87% of households buy food from wet markets and supermarkets, respectively (Table 5). However, there is a notable difference between the purchasing frequencies at wet markets and supermarkets. About 70% of households use wet markets at least five days a week, while the number for supermarkets is only about 17%.

Table 5. Frequency of Patronage of Wet Markets and Supermarkets.

Frequency (at Least)	Supermarkets		Wet Markets	
	No. of Households	%	No. of Households	%
Five days a week	176	16.7	843	75.2
Once a week	673	63.9	248	22.1
Once a month	187	17.8	26	2.3
Once in six months	16	1.5	3	0.3
Once a year	1	0.1	1	0.1
Total	1053	100.0	1121	100.00

3.2. Network Distance to Food Markets

Household locations were collected by the enumerators using android tablets with built-in GPS, with a positioning accuracy of 15 m. The location data of wet markets and supermarkets were calculated from the BaiduMap (map.baidu.com)—the most widely used online map service in China. Other outlets, such as small stores and mobile vendors, were not included in the analysis because of the logistical difficulty of plotting their GPS locations. Because the GPS in tablets is based on the WGS84 coordinate system but the BaiduMap uses the BD09 coordinate system where obfuscation were added based the WGS84 coordinate system [28], the GPS coordinates of the households' location were converted into BD09 coordinates before analysis.

The network distance from households to wet markets and supermarkets was calculated using Route Matrix API v2.0 Beta of BaiduMap which is an API (Application Programming Interface) providing the service for map distance calculation, developed by BaiduMap [29], where the travel distance between origins and destinations are calculated by summing the distance between multiple points based on road network [30]. The Route Matrix API v2.0 Beta provides three transport modes for network distance calculation: walking, by car and by bicycle. This study chose the pedestrian mode because walking and bicycling are the two principal transport modes for food shopping and, of these, walking is the most important. The survey found that about 90% of households bought their primary food within walking distance of their homes more than five times a week. The percentage of respondents who bought fresh vegetable, fruit and pork within walking distance were 93% ($N = 988$), 92% ($N = 974$) and 92% ($N = 957$), respectively. Another survey conducted in Nanjing in 2012 found that 61%, 20% and 17% of elderly Nanjing residents went shopping by walking, bicycle (including electric bicycle), and public transportation, respectively [31]. The figures for young adults were 40%, 37%, and 11% for young adults. We then calculated the walking distance from each household residence to the nearest wet market and the nearest supermarket.

3.3. Dependent and Independent Variables

Table 6 presents the definitions, expected signs, and summary statistics of variables used in this paper. The HDDS was used as the dependent variable. The primary factors seen as potentially influencing household dietary diversity were as follows:

- (1) *Proximity*: The distance to the nearest wet market and supermarket were used to reflect the proximity of a household to food stores. They are represented by independent variables *DTWM* and *DTSM*. The variable *DTNM* was generated by taking the minimum value of the variables *DTWM* and *DTSM* for each household, i.e., the distance to the nearest supermarket or wet market. Assuming that there is a negative correlation between physical proximity to food stores and household dietary diversity [1,4], the coefficients for the variables *DTWM*, *DTSM* and *DTNM* are hypothesized as negative.
- (2) *Household head*: The demographic characteristics of household heads have been considered possible determinants of household dietary diversity in previous studies [32–34]. The second set of independent variables—*HHA*, *HHE*, *HHM* and *HHG*—therefore represent the age, education level, marital status and gender of the household head, with positive coefficients (Table 6).

- (3) *Household size*: A third set of variables relates to household size or *HHS*. The value of *HHS* is the number of household members. A set of dummy variables was used for household size, i.e., *HHS2*, *HHS3*, *HHS4*, *HHS5*, *HHS6*, *HHS7*, *HHS8* and *HHS9*. As larger households tend to consume more diverse food items [35], they are expected to have a higher HDDS. The *HHS* and the eight dummy variables are hypothesized to have positive coefficients.
- (4) *Household structure*: Households were categorized into five types in the survey: female-centered, male-centered, nuclear, extended and other. The female-centered household has a female head with no male spouse/partner in the household but may include relatives, children, and friends. Male-centered households have no female spouse/partner. Nuclear households have a husband and wife (male/female partner) with or without children. Extended households refer to those with a male husband/partner and female wife/partner plus children and relatives. In China, the extended household usually includes grandparents, which influences family-based food consumption and could increase food diversity [1]. In the Nanjing survey, nuclear households were most common (57% of households), followed by extended households (29%), female-centered (7%) and male-centered (6%). The variable *SEXC* represents female-centered or male-centered households, and *EXTD* represents extended households. The variable *EXTD* is hypothesized to have positive coefficients.
- (5) *Household income*. Data on household monthly income were collected in the household survey and for the purposes of this analysis into income terciles. *HHIM* and *HHIH* represent the middle and high income terciles. As household income is positively correlated with dietary diversity in other studies [1,34], the variables *HHIM* and *HHIH* were projected to have positive coefficients.
- (6) *Housing type*. Type of housing is generally considered to be correlated with household food security [36,37]. The variable *HOUSE* was used to reflect the housing type of each household. In the case of Nanjing, the flat or apartment is the dominant housing type, accounting for 82% of all the surveyed households. The traditional dwelling is the second most common housing type, accounting for 13%. House and other types account for 3% and 2%, respectively. The variable *HOUSE* is assumed to have positive coefficients, which is a dummy variable whose value is 1 for those households living in a house or townhouse.
- (7) *Urban agriculture*. Some households living on the urban periphery engage in urban agriculture, and about 18% household grow some of their own food. The variable *CROPPING* was used to reflect those households growing food. The variable was hypothesized to have positive coefficients.

3.4. Regression Model

A Poisson model was used in this study to investigate the influence of physical access to food stores on household dietary diversity. The value of the dependent variable *HDDS* varies from 1 to 12, which is a count variable. The value of *HDDS* is assumed to have a Poisson distribution with expectation μ , for independent variables X_i , the Poisson regression model for expected counts can be specified as an exponential function [38]. For the dependent variable *HDDS*, the Poisson regression model is as follows:

$$\mu_i = E(HDDS_i | X_i) = \exp(\beta_0 + \beta_i X_i)$$

where *HDDS* is the HDDS of household i , X_i refers to the vector of independent variables, and β_0 and β_i are the constant and the coefficient vector for independent variables, respectively. The alternative log-linear model can be written as:

$$\ln(\mu_i) = \beta_0 + \beta_i X_i$$

Table 6. Dependent and Independent Variables.

Variable	Definition	Expected Sign	Mean	Std. Dev.	Skewness	Kurtosis
<i>HDDS</i>	Dependent variable, Household Dietary Diversity Score with value ranging from 0 to 12		7.83	2.31	−0.50	−0.26
<i>DTWM</i>	Distance to the nearest wet market (100 m)	−	15.16	16.31	2.28	5.51
<i>DTSM</i>	Distance to the nearest supermarket (100 m)	−	40.53	42.16	2.08	4.49
<i>DTNM</i>	Distance to the nearest wet market or supermarket (100 m)	−	13.09	12.86	2.22	6.13
<i>HHE</i>	Household head highest level of education, <i>HHE</i> = 1 for no formal schooling, <i>HHE</i> = 0 for otherwise	−	0.05	0.21	4.28	16.35
<i>HHM</i>	Household head marital status, <i>HHM</i> = 1 for unmarried, 0 for otherwise	−	0.02	0.15	6.48	40.01
<i>HHG</i>	Household head gender, <i>HHS</i> = 1 for male, 0 for otherwise	−	0.74	0.44	−1.11	−0.77
<i>HHA</i>	Household head age (year)	−	53.57	15.72	0.01	−0.71
<i>HHS</i>	Household size (person)	+	3.13	1.37	0.57	−0.18
<i>HHS2</i>	Dummy variable for household size, <i>HHS2</i> = 1 for 2 persons, 0 for otherwise	+	0.31	0.46	0.80	−1.36
<i>HHS3</i>	Dummy variable for household size, <i>HHS3</i> = 1 for 3 persons, 0 for otherwise	+	0.27	0.44	1.02	−0.96
<i>HHS4</i>	Dummy variable for household size, <i>HHS4</i> = 1 for 4 persons, 0 for otherwise	+	0.12	0.32	2.35	3.51
<i>HHS5</i>	Dummy variable for household size, <i>HHS5</i> = 1 for 5 persons, 0 for otherwise	+	0.18	0.39	1.61	0.59
<i>HHS6</i>	Dummy variable for household size, <i>HHS6</i> = 1 for 6 persons, 0 for otherwise	+	0.03	0.17	5.46	27.87
<i>HHS7</i>	Dummy variable for household size, <i>HHS7</i> = 1 for 7 persons, 0 for otherwise	+	0.00	0.05	13.72	186.66
<i>HHS8</i>	Dummy variable for household size, <i>HHS8</i> = 1 for 8 persons, 0 for otherwise	+	0.00	0.06	12.69	159.28
<i>HHS9</i>	Dummy variable for household size, <i>HHS9</i> = 9 for no less than 9 persons, 0 for otherwise	+	0.00	0.03	16.85	282.49
<i>EXTD</i>	Dummy variable for extended family, <i>EXTD</i> = 1 for extended family, 0 for otherwise	+	0.27	0.45	1.01	−0.98
<i>SEXC</i>	Dummy variable for male-centred or female-centred family, <i>SEXC</i> = 1 for male-centred or female-centred family, 0 for otherwise	−	0.12	0.33	2.27	3.17
<i>HHIM</i>	Dummy variable for net household income Tercile, <i>HHIM</i> = 1 for middle income (4501–8200 Yuan monthly), 0 for otherwise	+	0.31	0.46	0.81	−1.34
<i>HHIH</i>	Dummy variable for net household income Tercile, <i>HHIH</i> = 1 for high income (more than 8200 Yuan monthly), 0 for otherwise	+	0.33	0.47	0.72	−1.49
<i>HOUSE</i>	Dummy variable for dwelling type, <i>HOUSE</i> = 1 for house or town house, 0 for otherwise	+	0.01	0.11	8.53	70.94
<i>CROPPING</i>	Dummy variable for growing food, <i>CROPPING</i> = 1 for household growing its own food, 0 for otherwise	+	0.18	0.38	1.70	0.88

Both the variable *HHS* and the dummy variable set including *HHS2–HHS9* are used to reflect the size of a household, in terms of continuous and discrete numbers, respectively. Because of the one-child policy enforced in China between 1979 and 2015, nuclear households generally have a small household size. Thus, it is not reasonable for the model to include both the variable *HHS* and the dummy variable for household size. Households with more than 4 or 5 persons are also usually extended households. The independent variable *HHS* representing household size therefore reflects almost the same information as the dummy variable *EXTD* when the value of variable *HHS* is more than 4 or 5 persons, which makes it inappropriate to include both the variable *HHS* and the dummy variable *EXTD* in the analysis. Therefore, this study considered three different models including different sets of independent variables reflecting household size (variable *HHS* or dummy variables *HHS2–HHS9*) and household type (dummy variable *EXTD*) (see Model I, Model II and Model III in Table 7).

Table 7. Estimated Results of Poisson Model for Household Dietary Diversity.

Variable	Model I	Model II	Model III	Model IV	Model V	Model VI
<i>DTWM</i>	−0.0003	−0.0002	−0.0003			
<i>DTSM</i>	−0.0006 **	−0.0006 **	−0.0006 **			
<i>DTNM</i>				−0.0006	−0.0004	−0.0005
<i>HHE</i>	−0.1936 *	−0.1754 *	−0.1974 *	−0.2004 *	−0.1827 *	−0.2042 *
<i>HHM</i>	−0.2117 **	−0.1446	−0.2161 **	−0.2119 **	−0.1477	−0.2209 **
<i>HHG</i>	−0.0485	−0.0593	−0.0493	−0.0525	−0.0628 ***	−0.0512
<i>HHA</i>	0.0010	0.0011	0.0007	0.0011	0.0012	0.0009
<i>HHS</i>	0.0307 *			0.0306 *		
<i>HHS2</i>		0.1554 **			0.1526**	
<i>HHS3</i>		0.1846 *			0.1788 *	
<i>HHS4</i>		0.1867 *			0.1838 *	
<i>HHS5</i>		0.2683 *			0.2649 *	
<i>HHS6</i>		0.2106 **			0.2074 **	
<i>HHS7</i>		−0.5423			−0.5463	
<i>HHS8</i>		0.1987			0.1934	
<i>HHS9</i>		0.0240			0.0115	
<i>EXTD</i>			0.0825 *			0.0845 *
<i>SEXC</i>			−0.0406			−0.0325
<i>HHIM</i>	0.1235 *	0.1082 *	0.1226 *	0.1300 *	0.1154 *	0.1302 *
<i>HHIH</i>	0.0999 *	0.0895 *	0.1062*	0.1113 *	0.1019 *	0.1184 *
<i>HOUSE</i>	0.1867 ***	0.1870 ***	0.1856 ***	0.1927 **	0.1934 **	0.1911 **
<i>CROPPING</i>	0.0313	0.0240	0.0295	0.0138	0.0061	0.0121
Constant	1.9275 *	1.8514 *	2.0169 *	1.8971 *	1.8237 *	1.9831 *
N	858	858	860	858	858	860
LR chi ²	75.9900 *	87.6000*	76.8700 *	71.4600	82.8800	72.3800
Pseudo R ²	0.0194	0.0224	0.0196	0.0182	0.0211	0.0184
Log likelihood	−1921.5824	−1915.7798	−1925.2048	−1923.8491	−1918.1398	−1927.4492
AIC	3867.1650	3869.5600	3876.4100	3869.6980	3872.2800	3878.8980
BIC	3924.2200	3959.8970	3938.2500	3921.9990	3957.8630	3935.9820

Note: * denotes significant at 1%-level, ** significant at 5%-level, and *** significant at 10%-level.

To investigate the relationship between dietary diversity and proximity to the nearest supermarket or wet market, the variable *DTSM* and *DTWM* in Model I, Model II and Model III were replaced by the variable *DTNM*. As a result, Model IV, Model V and Model VI were generated and calculated, i.e., Model IV was built from the Model I by replacing the variable *DTSM* and *DTWM* with variable *DTNM*, and the same holds for Model V and Model VI. For the estimated results for Model IV, Model V and Model VI, see Table 7.

4. Models of Dietary Diversity

The models with different sets of independent variables are presented in Table 7. The correlation coefficient between the variable *DTWM* and *DTSM* is 0.2038 (significant at 1% level, $N = 1180$), the collinearity diagnostics results indicated that the issue of multicollinearity can be ignored. To mitigate

or avoid the possible problems due to a relatively large number of dummy variables being used, three groups of models with different number of dummy variables were estimated, and the three groups included Model I and Model IV, Model III and Model VI, and Model II and Model V, respectively. Model III includes those variables reflecting household structure and excluding those reflecting household size. Models I and II include those variables reflecting household size and excludes those reflecting household structure. Model I uses the variable *HHS* to measure household size rather than the set of dummy variables *HHS2–HHS9*, while Model II used the set of dummy variable *HHS2–HHS9* rather than the variable *HHS*. The three models perform satisfactorily in terms of goodness of fit. All six models are significant at the 1%-level. The signs for all the explanatory variables are consistent with expectations.

Table 6 presents the value of AIC and BIC. Smaller AIC and BIC indicate better models [38]. Model I has the smallest values of both AIC and BIC, suggesting that it is statistically superior to the other five models. As there are no major differences in AIC and BIC in the six models, the estimated results of the other five models are also worthy of being analyzed as they include different variables from Model I.

The results of this analysis indicate that physical access to wet markets is not a predictor of household dietary diversity in Nanjing. The signs of the estimated coefficients for the variable *DTWM* are consistent with expectation, but the estimated coefficients are statistically insignificant, which suggests that the distance to the nearest wet market is not a determinant of HDDS. However, the suppression effect caused by a “third variable” (*X2*, suppressor) could render the relationship between independent variable (*X1*) and dependent variable (*Y*) insignificant [39], smaller, or of opposite sign [40,41]. Households that are farthest from wet markets could have decreased odds of buying food from wet markets but increased probability of buying food from small food stores, so that purchase of food from small food stores could be a suppressor (the “third variable” *X2*). Thus, a new variable *SFSA* was generated, which refers to whether households buy food in small food stores. Following the testing procedure developed by Wen and Ye [42], the possible mediation and suppression effects of the variable *SFSA* were tested. The results indicate that there are no mediation or suppression effects for the variables *DTWM* and *SFSA*. This confirms that distance to wet markets is not a predictor or determinant of urban household dietary diversity in Nanjing.

The estimation results also suggest that physical access to supermarkets has a limited influence on household dietary diversity. The estimated coefficients of the variable *DTSM* of Models I, II and III are all statistically significant at 5% level and the signs of the estimated coefficients are consistent with expectations. However, all the coefficients of the variable *DTSM* in Models I, II and III are quite small (Table 7). The factor by which the expected count changes can be calculated as $\text{Exp}(\beta)$ for a unit change in the explanatory variable, keeping other independent variables constant [43]. According to the estimated coefficients in Models I, II and III, for a unit increase of 100 m in the variable *DTSM* (distance to the nearest supermarket), the expected value of a household’s HDDS decreases by a factor of 0.9994 or 0.1 percent, which is a very small magnitude of change. Even for an increase of 10 units (1000 m) in the variable *DTSM*, the expected value of a household’s HDDS decreases by a factor of only 0.9934, or less than 1%. The test results also indicate that there is no mediation and suppression effect for the variable *DTSM* and variable *SFSA*. Therefore, the influence of the proximity to a supermarket on HDDS is also nearly negligible, regardless of the statistical significance of the estimated coefficients.

The estimation coefficients for the variable *DTNM* also indicate that proximity to the nearest wet market or supermarket is not a predictor of household dietary diversity. The signs of the estimated coefficients for the variable *DTNM* are consistent with expectations, but the estimated coefficients for the variable *DTNM* of Model IV, Model V and Model VI are statistically insignificant. The test of the mediation and suppression effects indicates that there are no effects for the variable *DTNM* and variable *SFSA* which suggests that physical access to wet markets or supermarkets is not a determinant of household dietary diversity. Thus, information regarding the estimated coefficients of the variable *DTWM*, *DTSM* and *DTNM* indicates that proximity to wet markets and supermarkets is not a predictor

or determinant of urban household dietary diversity. In other words, the difference in the distance to wet markets or supermarkets makes no difference to urban household dietary diversity in Nanjing.

5. Implications for Dietary Diversity

5.1. Wet Market Planning Policies

The insignificant statistical correlation between the distance to the nearest market and household dietary diversity in Nanjing does not necessarily mean that proximity to food outlets is not important for residents' access to diverse food items. It is therefore important to understand the underlying reasons for the insignificant correlation. The most important reason is that the food infrastructure development planning in Nanjing has led to relatively equal and convenient access to wet markets or supermarkets for all households. This relates to the "mayor responsible for vegetable basket" system launched by the Chinese central government in 1988.

The system makes mayors responsible for promoting the production of and securing the supply of non-grain food [44]. The mandatory system has ensured an extensive food supply network in Nanjing, and is the foundation for the high level of physical accessibility to food. Accessibility was further enhanced by the Development Plan for Vegetable Basket Project (2008–2012) issued by the Nanjing Municipal Government in 2008, which specifies that the construction of wet markets should be strengthened [45].

Food infrastructure, and particularly the development of wet markets, has been a requirement for the development of new residential communities in Nanjing since the early 2000s. In 2003, the Nanjing Municipal Government issued regulations on wet market planning and construction, which specified that each newly-developed residential community with a construction area over 50,000 square meters should construct a new wet market with an area no less than 1000 square meters [46,47]. In 2004, the Commodity Network Plan of Nanjing City planned to have a wet market with a service radius of 500–1000 m for every 30,000 residents [48]. In 2011, the Nanjing Municipal Government updated these standards and required a wet market with an area of no less than 2000 square meters and a service radius of 500 m for every 25,000 residents; and a wet market with an area no less than 1500 square meters for each town with a population larger than 20,000 [49]. According to the Plan of Commercial Network in Nanjing (2015–2030) for Public Consultation, more than 200 new wet markets will be established in Nanjing by 2030 [50]. Besides these food infrastructure planning policies, the Nanjing Municipal Government has implemented the policy of "fresh produce zones" in supermarkets. In 2011, Nanjing Municipal Government issued a policy document which required that no less than 20% of existing supermarkets' area and 30% for newly-opened supermarkets should be used for fresh produce retail [49].

The implementation of these policies regarding food market development and planning means that there is relatively easy access to wet markets and supermarkets in Nanjing. About 26%, 56%, 74% and 80% of the interviewed households had a network distance to the nearest wet market or supermarket of less than 0.5 km, 1.0 km, 1.5 km and 2.0 km, respectively (Table 8). Assuming a median walking speed for an adult of 4.5 km/h or 1.25 m/s [51], and a 15-min walk as the commonly accepted walking time in food studies [36,52], then anything up to about 1.1 km is an acceptable walking distance.

About 58% of the surveyed households' walking distance to the nearest wet market or supermarket was less than 1.1 km (Table 8). The average distance to the nearest wet market or supermarket was 1.2 km for those households that reported buying vegetables, fruits and meat from wet markets or supermarkets. Cycling is also a popular transportation mode in Nanjing. An average speed by bicycle of 6.05 km/h [53] would mean about 1.5 km for a 15-min or 2.0 km for a 20-min ride by bicycle. About 74% and 80% of the surveyed households had a cycling distance to the nearest wet market or supermarket of less than 1.5 km and 2.0 km, respectively.

Table 8. Distance from Households to the Nearest Wet Markets or Supermarkets.

Distance Range (m)	% of Households	Distance (m, \leq)	Cumulative Percent (% of Household)
0–500	25.9	500	25.9
501–1000	29.8	1000	55.8
1001–1500	15.5	1500	71.3
1500–2000	8.6	2000	79.8
2001–2500	5.2	2500	85.0
2501–3000	6.1	3000	91.1
>3000	8.9	≤ 7303	100.0

5.2. Offsetting Effect of Small Food Stores

Another factor that contributes to the high level of physical access to food in Nanjing could be the many small food stores, including small shops and *xiao mai bu* (family run small stores, which are often a window on the wall facing the main street, selling processed food, condiments, cigarettes and other small commercial goods), located within or near residential communities. The survey in 2015 shows that 35% of surveyed households buy food from small food stores and that 26% do so at least five days a week or once a week. Unfortunately, the massive number of small food stores in Nanjing make it nearly impossible to comprehensively geocode them. However, we should not ignore the important role of small food stores in household food accessibility.

There probably has been an offsetting effect of small food stores in ensuring food diversity for households who live relatively far away from wet markets and supermarkets. A study in New Orleans found that other types of stores did offset the relative lack of supermarkets for snack foods but not fresh produce [54]. The offsetting effect could also be true in Nanjing. As small food stores are close to residential communities, they could contribute to household dietary diversity in relatively underserved areas. This is a reasonable conclusion given that individual small food stores provide more than seven of the types of food included in the HDDS indicator. Additionally, the common clustering of small food stores further enhances the diversity of their supply. Unlike small stores in the US where food is more expensive compared to supermarkets and large grocery stores [36], supermarkets in China have no price advantage over wet markets [13]. The primary reason is that the labor cost and food waste of supermarkets is higher than that of wet markets, and, in most cases, wholesale markets are the main supplier for both supermarkets and wet markets, although some supermarkets have their own source of fresh produce or suppliers [13]. As the small shops can also obtain vegetables directly from peri-urban small-scale producers at lower costs than that from wholesale markets, wet markets have no price advantage over small-scale stores [13].

5.3. Local Food Purchasing Behavior

The high level of physical accessibility to food outlets in Nanjing is mirrored in the high proportion of households buying food in their neighborhood or within walking distance. According to the Hungry Cities Food Purchases Matrix used in the survey [55], more than 90% of households said they normally buy most fresh food items within their neighborhoods or within walking distance (Table 9). Specifically, 92–93% of households buy their fresh vegetables, fruit and pork in their neighborhoods or within walking distance. A slightly lower percentage buy fresh animal products in their neighborhoods or within walking distance: 89% for eggs, 88% for fresh shellfish, 86% for fresh lamb and 73% for milk. Table 9 shows that more than 90% of surveyed households bought their main food items in their neighborhoods or within walking distance. In contrast, only 58% of households were within easy walking distance (up to 1.1 km) of their nearest wet market or supermarket. The difference between 90% and 58% is 32%, which is offset by the presence of small food stores. This is further evidence that small-scale food stores contribute to access to food within neighborhoods, in addition to their offsetting effects where households are relatively far away from wet markets and supermarkets.

Table 9. Location of Food Outlets Where Fresh Food Items Normally Purchased.

Item	% Beyond Neighborhood	% within Neighborhood
Fresh/cooked vegetables	7.0	93.0
Fresh pork	7.9	92.1
Fresh fruit	8.2	91.8
Fresh chicken	8.7	91.3
Offal	8.8	91.2
Fresh fish	9.2	90.8
Fresh beef	10.0	90.0
Eggs	11.5	88.5
Fresh shellfish	11.7	88.3
Fresh lamb	14.1	85.9
Milk	26.8	73.2

Note: “Within” refers to within walking distance, “beyond” refers to beyond walking distance.

5.4. Household Demographic Factors and Dietary Diversity

This study also examined the impacts of other factors (including household size, structure and income) on dietary diversity. The estimation results indicate that, unlike distances to food outlets, household size, structure, and income all significantly influence household dietary diversity (Table 7). Those coefficients of variables in Model I and V are statistically significant and consistent with expectations, including the variables *HHS*, *HHS2–HHS6*, *EXTD*, *HHIM* and *HHIH*. The coefficients for the variable *HHS* in Models I and V were 0.0307 and 0.0306, respectively. For an increase in household size by one, a household’s mean HDDS increases by a factor of 1.03% or by 3.10%. This is also a small change considering that the mean HDDS is 7.83. The coefficients for variables *HHS2*, *HHS3*, *HHS4*, *HHS5* and *HHS6* are statistically significant in Models I and V. There are similar coefficient values for variables *HHS2*, *HHS3*, *HHS4*, *HHS5* and *HHS6* in Models I and V. The coefficients for variable *HHS7*, *HHS8* and *HHS9* are not statistically significant in both models. This indicates that those households with 2–6 members have a higher HDDS than one-person households. Compared with the reference category of households with one person, multi-person households have an expected HDDS value increase of 17% (2 persons), 20% (3), 21% (4), 31% (5) and 23% (6) (based on the estimated coefficients in Model I). The variable *HHS5* has the highest coefficient among variables *HHS2–HHS6*. Due to the one-child policy, a five-person household usually means a household with one child, parents and grandparents (which is also categorized as an extended household). The coefficients for the variable *EXTD* were 0.0825 and 0.0845 in Model III and Model VI, respectively. Being an extended household increases the value of HDDS by about 9% (8.6% and 8.8% for Model III and Model VI, respectively). This indicates that household size and household structure have a moderate impact on household dietary diversity.

Extended households are relatively common in Nanjing, making up just over one quarter of all the surveyed households (households were sampled in the daytime when it was more likely that retired people were home, but employed people were not). The relatively high percentage of extended households diminishes the sensitivity of household dietary diversity to physical access to wet markets and supermarkets. Another study has indicated that household structure plays an important role in Chinese family-based food consumption [35]. Dual-career families (where both husband and wife work) are common in China. This means that it is the grandparents in extended households who buy the food and do most of the cooking and other domestic work [35]. In addition to extended households with three generations living in one dwelling, it is also common for grandparents to live in different dwellings within a short distance from the household of their adult children and grandchild and are commonly involved in the food purchasing and preparation for their children’s household [35]. As retired grandparents in extended households have more flexibility in terms of time and food purchase location, they are less sensitive to the shopping distance than young family members who devote most of their time to work. As a result, support from grandparents could make

the HDDS of extended households and some nuclear households less sensitive to the distance to wet markets and supermarkets than households without the support of grandparents.

The estimation results also suggest that some characteristics of household heads are predictors of household dietary diversity. The coefficients for the variable *HHE* and *HHM* are significantly negative. Being a household with an unmarried household head decreases the expected HDDS by 18%, compared with other households. Being a household with a household head without formal schooling decreases the expected HDDS by 19%, compared to a household with a household head with formal schooling (calculated based on the estimated Model I). However, the coefficients for the variable *HHA* (household head age) are not statistically significant, and neither are the coefficients for the variable *HHG* (household head gender) except in Model V. This is consistent with previous studies about household dietary diversity in China [1].

5.5. Household Income and Dietary Diversity

The significant positive coefficients for the variables reflecting household income and housing type (*HHIM*, *HHIH* and *HOUSE*) indicate that income is an important determinant of urban household dietary diversity. An increase in household income contributes to an increase in dietary diversity. Middle- and high-income households have a higher HDDS than low-income households. Being a middle-income household increases the expected HDDS by about 13% compared to a low-income household (mean of 13.1%, 11.4%, 13%, 13.9%, 12.2% and 13.9% for Model I, Model II, Model III, Model IV, Model V and Model VI, respectively). Being a high-income household increases the value of HDDS by about 11%.

In Nanjing, three-quarters of households live in apartments, with only a small proportion (2.4%) of wealthier households living in houses. The significant positive coefficients of the variable *HOUSE* suggest that households living in houses have higher dietary diversity. This is reflected in the 21% increase of HDDS of households living in houses, compared to low-income households. Other studies indicate that an increase in household income increases a household's economic access to food [56].

Increased income could contribute to dietary diversity by improving a household's transport facilities and food-preserving facilities. Electric bicycles, for example, are a faster and more expensive vehicle than traditional bicycles (priced about 10 times higher). The speed limit of an electric bicycle is 20 km/h, which means that the travel distance of ten minutes by electric bicycle is about 3 km. Our spatial analysis found that more than 90% of households had a network distance to the nearest wet market or supermarket of less than 3 km. The high-level of food accessibility is further enhanced by the increasing popularity of private cars in Nanjing. On average, there were 59.7 electric bicycles and 40.4 private cars per 100 urban households in 2015 [23]. In 2012, 10% of young adults and 1% of the elderly in Nanjing shopped for food by car [31]. The prevalence of refrigerators may also contribute to dietary diversity. In 2016, there were 102.4 and 109.5 refrigerators per 100 urban and rural households, respectively [23].

5.6. Urban Agriculture and Dietary Diversity

Although the estimated coefficients for the variable *CROPPING* are positive and the signs are consistent with expectation, the coefficients are statistically insignificant. This indicates that whether households grow their own food or not does not significantly influence dietary diversity. This is simply because urban farming in Nanjing has very limited access to land and thus is unable to produce a significant quantity of food. Moreover, even in the peri-urban or rural areas, the variety of produce is constrained by the size of farms and seasonality, which does not contribute to household dietary diversity.

6. Conclusions

This paper shows that, in contrast to studies in other contexts where proximity to food stores is one of the determinants of household dietary diversity [1,57], the distance from the household home

to the nearest wet market or supermarket has no significant impact on household dietary diversity in Nanjing. The coefficients for the distance to the nearest wet market are not statistically significant. The coefficients for distance to the nearest supermarket are of statistical significance but no economic significance or practical significance, as the very small coefficients indicate that distance to the nearest supermarket has no noticeable impact on household dietary diversity. However, these results do not necessarily indicate that the distance to food outlets is not important for household dietary diversity in other contexts. Indeed, the high level of food accessibility, thanks to the spatially dense food supply network in Nanjing, diminishes the correlation between distance and dietary diversity. Small food stores, together with wet markets and supermarkets, have created a favorable food environment in terms of physical access to food, which in turn leads to a non-significant relationship between the proximity to wet markets or supermarkets and household dietary diversity. The spatial distribution of wet markets, supermarkets and small-scale food stores constitute a favorable food environment in term of geographic access to food, which results in a relatively equal geographical access to food outlets. Such access decouples any linkage between the proximity to wet markets or supermarkets and household dietary diversity.

The study also found that various factors contribute to the non-significant influence of distance to the nearest wet market and supermarket. These include relatively high accessibility to food outlets, the prevalence of three-generation extended household structure, and household income. Extended households with three generations are less sensitive to the distance to wet markets and supermarkets because the grandparents who conduct most food purchasing and cooking in the households are more flexible in terms of time and food purchase location. In addition, higher household income and better transport and the popularity of refrigerators all contribute to the insignificance of the proximity to wet markets or supermarkets in determining urban household dietary diversity.

The implications of this study for food system planning in terms of urban land use governance are twofold. First, it is important to achieve high access to food by allowing and encouraging mixed land use for food outlets within or close to residential communities. Most wet markets and supermarkets in Nanjing are located close to residential communities, and small food stores are even located within residential communities. The policies that encourage mixed land use for food outlets have greatly enhanced residents' physical accessibility to food outlets. This is not only the situation in Nanjing but also common in other Chinese cities. Second, it is important to include wet markets in urban infrastructure planning systems, and making the construction of wet markets a requirement for the development plan of new residential areas can be an effective tool to improve and secure physical access to food outlets.

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