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Spatial determinants of urban wet market vendor profit in Nanjing, China



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Xinxian Qi^a, Zhenzhong Si^b, Taiyang Zhong^{a,**}, Xianjin Huang^{a,*}, Jonathan Crush^b

^a School of Geography and Ocean Science, Nanjing University, 163 Xianlin Avenue, Nanjing, 210023, China
^b Balsillie School of International Affairs, 67 Erb St West, Waterloo, ON, N2L 6C2, Canada

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ABSTRACT

Wet markets play an important role in urban food security in many Asian countries. Although the American Planning Association (APA) proposed in 2007 that food planning should focus on the business status and potential of food retailing, existing research pays more attention to the food accessibility of urban residents and limited research has been conducted on the profit of wet market vendors and factors determining its spatial variations. Therefore, a three-agent analytical framework for determinants of urban wet market vendor profit was developed. Based on the survey data of 1,119 small food enterprises in Nanjing, this study employs the spatial analytical method Geodetector to explore the spatial differentiation of the vendor's profits and its determinants. The study shows obvious spatial differentiation in the profits of wet market vendors across the city and draws several conclusions. Profitability is mainly related to the demographic features of vendors, their business expenses, and payment schemes. It is also related to broader socioeconomic factors at the district level, including local GDP, average income, urban infrastructure, and number of residential neighborhoods. The characteristics of vendors and their businesses have a more significant relationship with business profit than district socio-economic factors. There is also a strong mutual enhancement effect among these factors. Almost all identified determinants of profitability are stronger in peri-urban than urban areas. Therefore, there is greater potential for increasing peri-urban vendors' profits by changing these variables.

1. Introduction

Urban food provision has increased its importance in China's food security issues due to rapid urbanization and rapid changes in the urban food system. With the majority of the world's population now residing in urban centres (UNDESA, 2015), China's urbanization increased from 18% of the total population in 1978 to 58% in 2017 (NBS, 2018). It is expected to exceed 70% by 2030 (State Council, 2017). Food security is a central social and economic requirement for sustainable urban development in China (Si, Regnier-Davies, & Scott, 2017). Diverse food sources, including both modern and traditional food outlets, play a pivotal role in determining levels of urban food security in Chinese cities. The urban food supply system includes supermarkets, wet market retailers, small food stores, and street vendors. But they do not compete extensively among each other (Bai, Wahl, & McCluskey, 2008). Residents of Chinese cities tend to shop for processed and packaged food in supermarkets and fresh produce, especially vegetables, in wet markets (Zhang & Pan, 2013). Traditional marketing channels, particularly wet markets, dominate the retailing of vegetables and meat (Gorton, Sauer, & Supatpongkul, 2011; Si & Zhong, 2018), even the well-developed economy of Hong Kong operates this way (Goldman, Krider, & Ram-aswami, 1999). Besides vegetables and meat, wet markets specialize in fruit, aquatic products (such as live fish and shrimp) and staple foods (such as rice and other grains and flours) (Zhong et al., 2018).

Vendors in urban wet markets have played an important role in China's urban food retailing. In the early 2000s, the Chinese government launched a program, known as *nonggaichao* in Chinese, to convert wet markets into supermarkets as part of urban renewal plans. However, the program failed because wet markets carry a variety of fresh foods at lower cost. Although both supermarkets and wet market vendors procure fresh food from wholesale markets, wet market vendors avoid higher labor and operating costs which are all passed to consumers through higher prices, thus providing a price advantage over supermarkets (Goldman, 2000; Zhang & Pan, 2013). With the failure of the nonggaichao campaign in China, supermarkets became less competitive than wet markets (Hu, Reardon, Rozelle, Timmer, & Wang, 2010; Zhang

* Corresponding author.

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^{**} Corresponding author.

E-mail addresses: zty@nju.edu.cn (T. Zhong), hxj369@nju.edu.cn (X. Huang).

& Pan, 2013). As a result, wet markets play an increasingly important role in China's food security (Si, Scott, & McCordic, 2016). A previous study of Nanjing showed that the vast majority (93%) of households had accessed food from wet markets in the previous year. Among these patrons, 75% visited wet markets at least five days a week, indicating the high degree of accessibility of wet markets in the city (Si & Zhong, 2018). A wet market can accommodate approximately 40 stalls, which means it can provide 80–100 employment positions (including vendors and management staff) (Zhong et al., 2019).

Despite their important role, wet markets are still under-studied and insufficiently taken into account in food security policies. Existing studies have focused more on the quality and safety of food provided at the wet markets (Bougoure & Lee, 2009; Huang, Tsai, & Chen, 2015), consumer preference (Bai et al., 2008; Goldman, Ramaswami, & Krider, 2002) and psychological satisfaction from wet market shopping (Maruyama & Wu, 2014). Others have looked at price advantage (Cui, 2009) and the diversity of fresh produce (Si et al., 2016). Obviously, most existing research evaluated the operation of wet market from the perspective of consumers, but few focus on the profitability of wet market vendors. As APA (2007) proposed that urban planners should understand the economic impacts and future potential of food retailing. It's crucial to take into consideration the operating condition of food retailing and its determinants, in order to support urban planning. However, the nature of wet market businesses and the factors that affect their profitability have not been addressed. 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 (NUPB, 2017; Zhong et al., 2018). This suggests government recognition of the important role of wet markets in maintaining urban food security. However, urban commercial network planning only takes into account indicators of public facilities per capita (Xuan & Chen, 2006), ignoring the sustainability of the operations of the retailers. In addition, the profitability of wet market vendors is also an important factor to be considered for the inclusive growth of an urban food environment (Crush, 2016).

This paper provides a novel perspective on wet market food retailers' operating conditions in Nanjing. The main objectives of the study are (a) to examine wet market vendors' operating conditions using data from the Hungry Cities Partnership (HCP) food retailer survey of the city in 2017; (b) analyze the spatial determinants of wet market vendor profits; and (c) identify the significance of the impacts of these factors and the relationships between them using a geographical detector model.

2. The determinants of urban food retailing: literature review

Existing studies of the influencing factors of various food retailing formats in general provide a strong reference for understanding the impact factors of wet markets, a food retailing format with east Asian characteristics. According to the existing research, there are three main clusters that determine urban food retailing. The first cluster is the spatial arrangement and spatial heterogeneity of food retailing, and the second cluster is accessibility and food planning. These two clusters are mainly influenced by the government's planning and policies. The third cluster is the strategies and characteristics of the vendors, which is mainly influenced by wet market managers and vendors themselves.

2.1. Spatial heterogeneity in food retailing

Existing studies identified the spatial heterogeneity in food retailing (Eltholth, Fornace, Grace, Rushton, & Häsler, 2015; Riley & Legwegoh, 2014; Short, Guthman, & Raskin, 2007). There are studies using spatial analysis to analyze the spatial differentiation of urban food environment (Luan, Law, & Quick, 2015). Although food deserts widely exist, especially in more deprived areas (Caraher, Dixon, Lang, & Carr-Hill, 1998), some studies show that there are more food stores in the more deprived localities and districts (Cummins & Macintyre, 1999). In addition, Sabet

and Azharianfarb (2017) show that there are not only differences but also linkages between urban and rural food retailing, that is, peri-urban areas play an important role in providing food to urban consumers. Therefore, the underlying mechanism of the spatial differentiation of food retailing is unclear.

In general, few studies have explored the spatial differences of wet market vendors' management strategies, profits, operational status and operational structure (the percentage of different types of food sold by retailers), from the perspective of wet market vendors. The factors that lead to these spatial differences also haven't been explored. Not only will there be spatial heterogeneity of food security, but also the different numbers of immigrants in different regions of the city will indirectly lead to differences in the profitability of wet market vendors. Therefore, this study puts forward the hypothesis that the profit ofwet market vendors also has spatial heterogeneity.

2.2. Governmental interventions and food retailing

Accessibility has been an important concern of urban food system governance which could shape urban food retailing. A large number of previous studies focused on the impact of food accessibility on food security (Battersby & Peyton, 2014; Charreire et al., 2010; Chen & Clark, 2015; Dai & Wang, 2016; Pothukuchi, 2005). There are also studies to assess the food environment from the perspective of urban residents through time and space accessibility (Horner & Wood, 2014; Luan et al., 2015), and that explore the differentiation of food security across space (Eckert & Shetty, 2011; Riley & Legwegoh, 2014). Transportation was also proven to affect consumers' choice of food retail (Bai et al., 2008). In addition, some studies focus on the spatial distribution of food retailing in response to urban "food deserts" (Cummins & Macintyre, 1999). Therefore, food accessibility largely affects the operation of food retailing. Of course, factors affecting food accessibility include location, audience size, infrastructure and local economic and social development (Bai et al., 2008). However, urban food security is rarely studied from the perspective of food retailers' operating conditions.

In order to enhance sustainable urban food environments, urban planners are paying increasing attention to urban food systems (Pothukuchi, 2005; Pothukuchi & Kaufman, 2000). Planners continuously consider the adequacy of food supply (Conrad, Chui, Jahns, Peters, & Griffin, 2017), the resilience of the urban food system (Biehl, Buzogany, Baja, & Neff, 2018), the effect of zoning ordinances on local food systems (Haines, 2018), and food availability from the perspective of customers (Peng and Kaza,)-concerns that are still preeminent today. Besides, There is also a growing concern about the health impacts of food systems planning (Barnhill et al., 2018; Ledoux, Vojnovic, Manning Thomas, & Pothukuchi, 2016). Nevertheless, the business status of urban food retailing is emerging as a theme in this discussion (Donofrio, 2007). APA (2007) proposed that urban planners should understand the economic impacts and future potential of food retailing. Obviously, the landscape of food retail business is the result of food planning taking many factors into account. However, traditional planners are more concerned with how to arrange food retailing to increase the availability of food in order to improve community food security when creating a food system plan (Pothukuchi & Kaufman, 2000). Yet, these plans ignore the economic viability of food retailers. That is, whether retail vendors can generate profit sustainably and how their economic viability is related to spatial determinants.

2.3. Vendors' characteristics and strategies on food retailing

Besides those factors mentioned above, vendors are not insignificant in the formation of the landscape of urban food retailing. During the early 1990s of UK's 'store war', the expansion strategy of food stores greatly promoted the development of food retailing (Wrigley, 1998). Business strategy is not only particularly important for large food enterprises, but also for small food retail vendors. Sustainable food retailing has also been enhanced through the strategy of food vendors adjusting their locations and business scale with local land markets and planning (Guy, 1996). Thus a flexible business strategy adopted by food suppliers is to contribute to the sustainable development of food retailing. However, the same food business strategy may have different effects on food retailing, such as the case of UK and Spain from the perspective of a national scale (Flavián, Haberberg, & Polo, 2002). For vendors in a relatively smaller scale area, especially wet market vendors, flexibility and vigorous are their characteristics (Li, Ren, Hu, & Wang, 2018). Cresswell's (2010) theory of mobility showed that vendors respond to adverse environmental factors by a spatial strategy such as moving.

Guy (1996) found through his research on Cardiff food retailing that characteristics of the vendors (particularly size and location) were strongly related to the business conditions. A survey of street vendors in Thailand also showed that business knowledge is a prerequisite for achieving higher profit (Nirathron, 2005), which is related not only to the educational level of street vendors but also to their sales strategies. Although traditional market retailers are also affected by competition from emerging supermarkets; market infrastructure and organization of the street vendors are considered to be the major determinants for operations (Suryadarma, Poesoro, AkhmadiBudiyati, Rosfadhila, & Suryahadi, 2010).

In summary, the characteristics and business strategies of the vendors are important factors for the sustainable development of food retailing. However, these factors' impacts and their correlation will also show variance in different areas.

3. Tracing the determinants of wet market vendor profit: the multi-agent analytical framework

The previous review indicates that food retailing is affected by spatial location, planning, characteristics of the vendors, business strategies and so on. For wet markets especially, these influencing factors mainly pertain to three agents; the government, market managers and vendors themselves. The government mainly affects the location, customer size and infrastructure around the market through urban planning and distributing the wet market, at the same time, government affects the socioeconomic conditions through macro-policy adjustments. The wet market manager controls the admission and management of wet market vendors which will indirectly affect their profit. In this process, wet market managers actually act as a bridge connecting the government to the vendors. Wet market vendors mainly affect the profit by their own characteristics and business strategies. (see Fig. 1)

However, these factors not only act on the profit of wet market vendors, but also exhibit an interactive relationship in between themselves. For example, previous studies have shown that the business strategies of vendors are also affected by local economic and social development and planning (Guy, 1996). In addition, these factors not only interact directly or indirectly, but also connect spatially. Due to the influence of the government on the planning and policy of public facilities, the spatial heterogeneity of the layout, customer size and surrounding infrastructure of the wet market will affect the profit of the vendors. From the perspective of the vendors themselves, the unbalanced urbanization of the city will lead to spatial heterogeneity in the characteristics and strategies of wet market vendors, which will consequently affect their profits. Therefore, it is urgently necessary to explore thespatial determinants through this research framework with spatially analytical methods, and to clarify the relationships between these factors.

4. Material and methods

4.1. Study area

Nanjing has a population of 8.28 million and is the capital city of



Fig. 1. Multi-agent analytical framework for determinants of urban wet market vendor profit.

Jiangsu province (JBS, 2018). Located in the southwest of Jiangsu, Nanjing is about 300 km from Shanghai. Existing studies conducted by the Hungry Cities Partnership (HCP) show that Nanjing has a high level of household food security: the average HFIAS (Household Food Insecurity Access Score) was a very low 0.61, indicating that very few households experienced any of the usual symptoms of food insecurity (Si et al., 2016). Wet markets are one of the major types of food retail outlets in Nanjing and there were 351 wet markets in the city in 2017. The Nanjing municipality has 11 districts with variable population densities and economic strength. To compare the importance of factors affecting wet market vendor operations in urban and peri-urban areas of the city, Gulou, Qinhuai, Xuanwu, Jianye, Yuhuatai and Qixia districts were classified as urban (based on population density of greater than 1, 500 people per sq km), and Pukou, Jiangning, Liuhe, Gaochun, and Lishui districts were classified as peri-urban (Table 1).

4.2. Data collection and preprocessing

The HCP conducted a city-wide survey of 1,119 small food retailers in Nanjing in 2017, including wet market vendors, small food stores, and street vendors near wet markets(Fig. 2). The wet markets surveyed were randomly sampled from the 350 wet markets in Nanjing in 2017. In total, 42 wet markets in 11 districts were sampled. Students were sent out to collect information about the number and relative locations of vendors within and surrounding these markets. We then numbered these vendors and randomly sampled them based on the resources we have. Two rounds of survey were conducted. The first round surveyed 864 vendors, including wet market vendors, small food shop owners and street vendors, both in and within 50 m of these randomly selected markets. The second round targeted youth vendors and surveyed 255 vendors who were 35 years of age or younger. The survey was conducted by undergraduate and graduate students from Nanjing University using digital survey instruments on android tablets. The data were then uploaded and synthesized on the online Ona database. After data review and cleaning, a total of 555 vendors provided data on their business profits, and 383 of them were wet market vendors.

In addition to the survey, district-level socioeconomic data were collected from the Nanjing Statistical Yearbook 2017 on factors such as the gross domestic product (GDP), disposable income per capita, and population of sampled districts. Metro station data were collected from the official website of Nanjing Metro at http://www.njmetro.com.cn/. Data on residential neighborhoods and wet market location were collected from the BaiduMap (map.baidu.com)—the most widely used online map service in China. The accessibility data used in the paper were calculated from time/cost-based Nanjing wet market accessibility calculation (Tang, 2018).

4.3. Definition of variables

The dependent variable used in the study was wet market vendor

Table 1

Population and wet market distribution by distri	ct.
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Fig. 2. Location of surveyed vendors in Nanjing.

profits (represents the net profit of the vendor last month by asking "In the last month, what was the net profit you earned at this business?" in Chinese). The primary factors seen as potentially related to wet market vendor profits were as follows:

- *Age*: The older the age of a vendor, the more sales experience they have, but their ability to physically operate a business may also decline. The impact of age is therefore uncertain.
- Sex: There were 22.0% more female retailers than men in this survey. Studies in other contexts suggest that women are more concentrated in the food sector (Grant, 2013). However, men have an advantage in jobs requiring long-distance travel, thus women in peri-urban areas are particularly spatially constrained in local labor markets (Hanson

Types	Districts	Population (million)	% of Population	Area (km ²)	Density (people/km ²)	No. of Wet Markets
Urban	Gulou	1.25	15.09	53.00	23,574	54
	Qinhuai	1.00	12.12	49.11	20,438	27
	Xuanwu	0.64	7.78	75.46	8,538	21
	Jianye	0.46	5.55	82.93	5,543	25
	Yuhuatai	0.44	5.27	132.39	3,296	27
	Qixia	0.69	8.37	395.44	1,753	38
Peri-urban	Pukou	0.77	9.30	910.49	846	37
	Jiangning	1.22	14.68	1,563.32	778	56
	Liuhe	0.94	11.41	1,470.99	642	37
	Gaochun	0.43	5.20	790.23	545	16
	Lishui	0.43	5.22	1,063.67	407	13
Total		8.28	100	6,587.03	1,257	351

Source: Statistics Yearbook of Nanjing (NSB, 2018).

& Pratt, 1988). The impact of the sex of the operator on profitability is uncertain.

- *Education*: The higher the educational level of wet market vendors, the better they know how to operate and make decisions, so we hypothesize that the educational level of vendors has a positive effect on income and profits.
- *Diversity*: Diversity refers to the types of food sold by wet market vendors. The survey counted 21 types of food. The more types of food for sale, the better the vendors can meet their customers' needs and the more profit they can potentially make. However, carrying more food types could increase costs and risks, so the impact of diversity is uncertain.
- *Expenses*: According to the survey, the major expenses include the cost of food bought for sale (91% of vendors in the previous month), rent (82%) and utilities (78%). Greater input costs are associated with greater economic returns, but there are also invisible market risks such as fluctuations in market prices, so the impact of input expenses is uncertain.
- *Mobile payment*: The Ipsos (2017) report shows that 58% of fruit vendors in Chinese markets accept mobile payments. Mobile payment has become an important factor that contributes to the prosperity of the retail industry. Therefore, we hypothesize that the impact of offering mobile payment is positive.
- *GDP*: GDP is an indicator of the level of regional economic development of the district. Economic development is also an important indicator of the food retail business environment (Nirathron, 2005; Yasmeen, 2001), and as GDP increases there should be a positive impact on profits.
- *Income*: Generally speaking, per capita disposable income in a district reflects the living standards of residents, it also indirectly reflects consumers' food retail choices (Veeck & Veeck, 2000), and the two are positively related, so the impact of this indicator is hypothesized as positive.
- *Metro*: Transportation infrastructure has proven to be an important factor influencing food security in a city (Frayne & McCordic, 2015), and it also affects the operations of wet market vendors (Zhang & Pan, 2013). The number of metro stations per unit area is used to roughly measure the infrastructure of a district. Easy access to transportation infrastructure such as the metro system will bring in more customers so the impact of the metro system should be positive.
- Accessibility: Accessibility is indicated by the time it takes to get to the market (Tang, 2018) and is an important factor affecting consumers' access to food (Pothukuchi, 2005; Tacoli, 2017). The higher the value, the longer the time it takes to get to the wet market, and the less likely the wet market vendor will be able to get customers, so the impact of accessibility here is negative.
- *Residential neighborhoods*: The number of residential neighbourhoods in a district reflects the spatial concentration of the residential population. Population size has an important effect on the sustainability of a market (Sabet & Azharianfarb, 2017). The more residential communities in a district, the more customers the wet markets in this district will have, so the impact of the number of residential communities is positive.
- *Location entropy*: The location entropy refers to the ratio of the number of wet markets per capita in each district to the number of wet markets per capita in Nanjing (Tang, 2018). A higher location entropy index in a district means an advantageous position compared to other districts. Therefore, we infer that the impact of the location entropy index is positive.
- *Distance*: Distance refers to the distance between a vendor and his or her food supplier. Previous research shows that the typical food supplier of wet market vendors is the wholesale market (Zhang & Pan, 2013). As a matter of fact, most wholesales are located in peri-urban areas, which makes the distance between urban and peri-urban areas in the food supply significantly different. In general, the further the vendor is away from the wholesale market, the higher

the transport costs, so distance should have a negative impact on the profits of wet market vendors.

Table 2 summarises these variables, indicating how each is quantified, whether the expected sign is negative or positive, and the mean and standard deviation of the vendors sampled.

4.4. Geographical detector model

The geographical detector model was used to examine the spatial distribution of wet market vendors' profits and their relationship with the explanatory variables in Nanjing. The model is a spatial variation analytical method first proposed by Wang et al. (2010). The basic idea of the model is to test the association between the explanatory variables and the dependent variable through analyzing the consistency of their spatial distribution. If the explanatory variables are closely associated with the dependent variable, their spatial distributions tend to be similar.

Compared to traditional regression models, the geographical detector model is capable of handling categorical independent variables without considering multicollinearity among the explanatory variables (Wang, Zhang, & Fu, 2016). In this study, the factors detector and interaction detector were used to examine the spatial determinants of wet market vendors' profits and the factors' interaction effect. The factor detector model is as follows:

$$q=1-\frac{1}{N\sigma^2}\sum_{h=1}^L N_h\sigma_h^2$$

where q is the power of determinants, an index that is the same as effect intensity and ranges from 0 to 1. A q value of 0 means that little of the variance of the dependent variable is explained by the explanatory variables (where the total variance of the dependent variable is approaching the variance of the dependent variable in each subcategory of the explanatory variables i.e. the dependent variable is likely to be randomly distributed in each subcategory of the explanatory variables). A q value of 1 indicates that the variance of the dependent variable can be completely explained by the explanatory variables, where the dependent variable tends to be the same without any variance within each subcategory of the explanatory variables. That is, the bigger the qvalue, the greater the effect the explanatory variables have. Compared with other spatial analysis methods, the q value of the Geodetector makes it easier to show the influence of independent variables on the dependent variable, and it is easier to compare.

N and σ^2 stand for the sample size of the study vendors and variance of wet market vendors' profits.

 N_h and σ_h^2 refer to the sample size in each subcategory and its corresponding variance for wet market vendors' profits. The interaction detector reveals whether the factors interact or lead to effect independently. In other words, whether the interaction of factor X_I and X_2 enhances or weakens impacts on effect Y, or a factor leads to effect independently. If $q(X_1 \cap X_2) > q(X_1) + q(X_2)$, it shows that X_I and X_2 are nonlinear enhance for Y. If $q(X_1 \cap X_2) = q(X_1) + q(X_2)$, it shows that X_I and X_2 are independent for Y. If $q(X_1 \cap X_2) > Max(q(X_1),q(X_2))$, it shows that X_I and X_2 are bi-enhance for Y. If $Min(q(X_1), q(X_2)) < q(X_1 \cap X_2) < Max(q(X_1),q(X_2))$, it shows that X_I and X_2 are uniweaken for Y. If $q(X_1 \cap X_2) < Min(q(X_1),q(X_2))$, it shows that X_I and X_2 are nonlinear weaken (See Fig. 3).

5. Results

5.1. Mapping vendor profitability

For anonymity concerns, the average profit (net profit of the vendor last month) of all wet market vendors in each district was first calculated. The average profits varied from district to district but for the city

Table 2

Statistical description of variables.

Variables	Types	Names	Variable description (unit)	Expected sign	Mean	Std.
Dependent variable	Operation state	Profits	Profit you earned at this business in last month (yuan)		9250.25	17519.09
Vendor level	Characteristics	Age	Age of wet market vendor	+/-	41.21	10.64
		Gender	Gender of wet market vendor (male for 1, female for 0)	+/-	0.45	0.50
		Education	1-7 correspond to the level of education	+	2.99	1.12
	Strategies	Diversity	1-21 correspond to the types of food sold by vendor	+/-	2.39	1.90
		Expenses	Total business expenses in last month (yuan)	+	54729.12	266303.10
		Mobile payment	Whether to accept customer mobile payment (yes for 1, no for 0)	+	0.53	0.50
District level	Socioeconomic	GDP	Gross domestic product (108yuan)	+	782.27	371.77
	status	Income	Disposable income per capita (yuan)	+	48902.73	3643.38
	Infrastructure	Metro	Number of metro stations per square kilometers	+	0.11	0.11
		Accessibility	The time cost accessibility value of the wet market (h)	-	2.92	3.1
	Customer size	Residential neighborhoods	Number of residential neighborhoods	+	633.18	240.33
	Locational	Location	Ratio of wet market and population (%)	+	0.96	0.25
	conditions	Distance	distance to the wholesale market (kilometers)	-	24.72	16.23

Graphical representation	Description	Interaction
▼ • • • • • • • • • • • • • • • • • • •	$q(X_1 \cap X_2) < Min(q(X_1), q(X_2))$	Weaken nonlinear
	$Min(q(X_1), q(X_2)) < q(X_1 \cap X_2) < Max(q(X_1), q(X_2))$	Weaken, uni-
	$q(X_1 \cap X_2) > Max(q(X_1), q(X_2))$	Enhance, bi-
••••••••••••••••••••••••••••••••••••••	$q(X_1 \cap X_2) = q(X_1) + q(X_2)$	Independent
••••••••••••••••••••••••••••••••••••••	$q(X_1 \cap X_2) > q(X_1) + q(X_2)$	Enhance, nonlinear
• $Min(q(X_1), q(X_2))$	• $Max(q(X_1), q(X_2))$ • $q(X_1) + q(X_2)$ $\bigvee q(X_1 \cap$	<i>X</i> ₂)

Fig. 3. Redefined interaction relationships, source: http://www.geodetector.org/.

as a whole, areas with higher vendor profits mostly clustered in the city centre, with the exception of Xuanwu District (Fig. 4).

The average profit of wet market vendors in each of the 11 districts is outlined from high to low in Table 3, Fig. 5 also shows the range of profits in each district. The greatest range was found in Jiangning District which is the largest district in Nanjing, there is still a big difference in the profits of wet market vendors within this district. The average profits of wet market vendors was higher in urban districts (9,412.35 CNY) than in peri-urban districts (8,942.01 CNY). This result verifies the hypothesis of spatial heterogeneity of wet market vendor profit proposed in Section 2.1.

Table 4 shows the average value of each of the 13 explanatory variables, divided by core urban and peri-urban districts. Five of the

Table 3					
Statistical	analysis	of range	of pro	ofits by	district.

Area	District	Profits (CNY)
Urban	Gulou	14,100.00
Urban	Yuhuatai	13,090.91
Peri-urban	Jiangning	11,607.28
Urban	Qinhuai	11,550.00
Peri-urban	Lishui	10,640.00
Urban	Qixia	8,125.00
Urban	Jianye	7,413.33
Peri-urban	Pukou	6,985.29
Urban	Xuanwu	6,661.29
Peri-urban	Liuhe	5,750.00
Peri-urban	Gaochun	3,197.06

variables - gender, food diversity, expenses, resident disposable income, and residential neighborhoods - had values that were significantly larger in urban areas than in peri-urban areas, while the values of the other variables were significantly smaller in urban districts. Such a comparison shows the differences between urban and peri-urban areas in the characteristics of vendors and regions. In terms of the characteristics of vendors, vendors in urban areas are younger, the food they sell is more diverse and they invest more. Peri-urban vendors, on the other hand, are largely female, have higher education levels and use mobile payments more often. From the perspective of district characteristics, the urban area has a higher disposable income per capita and a larger number of subway stations per unit area. Residents in urban areas have a higher accessibility to wet markets. There are more residential areas and better locations of wet markets in urban areas. However, the GDPs of the peri-urban areas are higher, and the distance from the vendors to the wholesale market is also further in peri-urban areas.

A city-wide mapping of the explanatory variables shows significant spatial heterogeneity and differences in spatial distribution (see Fig. 6). Disposable income has a clear visual core-edge spatial structure (Fig. 6i), and time-cost accessibility shows an obvious increase from the city centre to the periphery (Fig. 6j). Other factors have no obvious spatial characteristics. In order to further explore the relationship between these factors and vendor profits, additional spatial statistical analysis is needed.



Fig. 4. Average profit of sampled vendors in districts of Nanjing.



Fig. 5. Statistical Analysis of Range of Profits by District.

Note: In each box-plot, the top horizontal line represents the maximum value; the bottom horizontal line represents the minimum value; the upper border of the box represents the upper quartile; the lower border of the box represents the lower quartile; the middle line represents the median and the x represents the average value.

5.2. Explaining spatial variations in wet market vendor profits

The geographical detector model was used to identify the level of impact and the interactions between the factors that affect wet market vendor profits in Nanjing. As noted above, average vendor profit is the dependent variable, while the independent variables include both mean Table 4

Average value of explanatory variables in urban and peri-urban districts.

	Urban	Peri-Urban
Vendor Characteristics		
Age	41.16	41.30
Gender	0.47	0.42
Education	2.94	3.11
Diversity of products	2.56	2.08
Expenses	59,470.44	45,713.42
Mobile payment	0.51	0.57
District Characteristics		
GDP	683.47	900.82
Income	51,124.50	46,236.60
Metro	0.19	0.01
Accessibility	1.08	5.13
Neighborhoods	735.17	510.8
Distance	19.94	33.82
Location	1.02	0.90

Note: See Table 2 for units of measurement.

vendor characteristics and socioeconomic data for each district. To meet the requirements of the geographical detector model, all continuous variables were first discretized by SPSS 23.0. However, because the geographical detector model only measures the magnitude of driving factors, Spearman Correlation Analysis was also employed to identify if the impact of a certain factor was positive or negative (or the direction of effect).

Table 5 shows the magnitude of the q value, significance level, and direction of effect for each variable. It suggests that with the exception of age and product diversity, all of the detected variables have a significant impact on the spatial distribution of wet market vendor profits. On average, vendor characteristics contribute more to vendor profits than the socioeconomic character of the district in which the wet market is located, with the *q* value of vendor characteristics are generally higher than that of district characteristics. Vendor expenses had the most significant and positive relationship with profits, with a q value of 0.44. Although the effect of gender on the profits of wet market vendors was positive, its impact is minimal, with a q value of 0.02. Although the q value for age is 0.26, and the direction is negative, the impact of age is not significant, invalidating the consequence that the profitability of food vending is more likely to decline as the vendor gets older. The education level also positively affects profits, with a q value of 0.14. Accepting mobile payment is another factor positively affecting the profits of wet market vendors (q value of 0.18), although the widespread adoption of mobile payment in food retailing improves profitability in general. The distance between wet market vendors and the wholesale market has a negative impact on the profits of vendors, with a q value of 0.05. This is probably because the further away from the wholesale market a vendor is located, the higher the cost of transportation and the lower the profit.

In addition to the vendor characteristics, some aspects of the socioeconomic profile of the district where the vendors are located appear to have an impact on profitability. For example, district GDP and per capita disposable income, both with q values of 0.07, positively affect the profits of market vendors. Infrastructure (in the form of the number of metro stations per unit area) also has a positive impact, with a q value of 0.05. Accessibility negatively affects the profits of wet market vendors, with a q value of 0.06. Both of these factors illustrate the importance of urban infrastructure for the operation of food markets. The number of residential neighborhoods also has a positive impact on the profits of wet market vendors, with a q value of 0.07.

The geographical detector model not only detects the effect of a single variable but the effect of variable interactions on the dependent variable. Table 6 shows that the interactions between most explanatory variables exhibit nonlinear enhanced effects on wet market vendor profits, implying that interactive effects exceed the simple combined effects of separate variables. In particular, the interaction effect of age



Fig. 6. Spatial variation of explanatory variables, a is gender, b is age, c is education, d is diversity of food, e is mobile payment, f is expense, g is distance, h is GDP, i is resident disposable income, j is accessibility, k is residential neighborhoods, l is location entropy, m is numbers of metro per square kilometers.

Relationship between profits and independent variables.	Table 5
	Relationship between profits and independent variables.

	q statistic	p value	sign
Vendor Characteristics			
Age	0.26	0.107	-
Gender	0.02***	0.005	+
Education	0.14***	0.000	+
Diversity of products	0.03	0.995	_
Expenses	0.44***	0.00	+
Mobile payment	0.18***	0.000	+
District Characteristics			
GDP	0.07***	0.007	+
Income	0.07**	0.028	+
Metro	0.05**	0.042	+
Accessibility	0.06**	0.037	_
Neighborhoods	0.07**	0.012	+
Distance	0.05**	0.024	_
Location	0.08***	0.005	+

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

and expenses had the highest q value of 0.97, indicating that younger vendors who increase investments are most likely to increase their profits. Other interactions of note were between GDP and expenses (0.85), location and expenses (0.85), residential neighborhoods and expenses (0.83), distance and expenses (0.82), metro and expenses (0.78), and per capita disposable income and expenses (0.76). Whether

increased expenditures will lead to profit increases therefore depends upon at least two groups of factors: (a) local social and economic development, as reflected in GDP and per capita disposable income, and (b) location factors such as the number of residential neighborhoods, location and accessibility of the wet market, and distance to the wholesale market.

The analysis first compared the q values in urban and peri-urban regions. Most *q* values were higher in peri-urban districts (Fig. 7.). The highest *q* value was vendor expenses, which is 59% higher than in urban districts. The one exception is gender, where the impact of male ownership on profits is greater in urban than peri-urban areas. This is mainly because most of the wet market vendors live in peri-urban areas, and men have an advantage in jobs requiring long-distance travel from the peri-urban area to the city centre. In the urban districts, accessibility-indicated by the time it takes to get to the market-and the distance to the wholesale market have little effect on the profits of wet market vendors (q values of only 0.004 and 0.005 respectively). Although the average profit of wet market vendors in urban areas is greater than that in peri-urban areas, the effect of the impact factors is generally larger in peri-urban areas. In the peri-urban areas, the impacts of these factors on the profit of wet market vendors are more significant, which suggests that small food businesses in wet markets in peri-urban areas have the potential to become more profitable by adjusting the factors with policy instruments.

Table 6						
Interaction	of factors	affecting	wet r	narket	vendor	profits.

meracuon	included of factors ance ing wet market vehicle promo-												
Variable	Gen.	Age	Edu.	Div.	Mob.	Exp.	GDP	Inc.	Acc.	Res.	Loc.	Met.	Dis.
Gen.	0.022												
Age	0.350	0.256											
Edu.	0.165	0.499	0.139										
Div.	0.065	0.521	0.247	0.032									
Mob.	0.215	0.353	0.272	0.217	0.183								
Exp.	0.552	0.971	0.744	0.691	0.659	0.442							
GDP	0.111	0.525	0.301	0.184	0.263	0.847	0.069						
Inc.	0.111	0.502	0.279	0.160	0.264	0.761	0.089	0.067					
Acc.	0.101	0.392	0.241	0.125	0.244	0.629	0.089	0.078	0.060				
Res.	0.124	0.536	0.283	0.173	0.275	0.826	0.089	0.089	0.089	0.075			
Loc.	0.125	0.543	0.322	0.198	0.275	0.850	0.084	0.089	0.089	0.089	0.082		
Met.	0.080	0.505	0.290	0.134	0.243	0.780	0.089	0.089	0.086	0.089	0.089	0.050	
Dis.	0.084	0.494	0.261	0.144	0.243	0.818	0.077	0.089	0.078	0.089	0.089	0.089	0.047



Fig. 7. Comparison of urban and peri-urban factors affecting profits.

6. Conclusion and implications

The profitability of wet market vending in Nanjing demonstrates significant spatial variation. In general, vendors in urban districts make more profit than those in peri-urban districts. However, almost all the determinants of profitability have a greater impact on profit in periurban districts compared to urban districts. As a result, there is a greater potential for wet market vendors in peri-urban areas to increase profits through improving these factors. Overall, demographic factors (gender, age, education level) and business activities (including expenses and payment schemes) have a more significant impact on profitability than the socioeconomic character of the districts where vendors are located.

Expenses are the single determinant most associated with the profits of market vendors. Reducing rents and utilities expenses through subsidies could serve as a policy incentive for government to save vendors' utilities expenses to invest more on the fresh products and service, enhancing the competitiveness of wet market vendors. Whether a vendor offers mobile payment was also found to affect the profitability of wet market food retailing. The degree of acceptance of mobile payment by wet market vendors has a slightly higher impact on profits in peri-urban than urban areas. Urban infrastructure such as the number of metro stations per unit area and food accessibility also has a greater impact on profitability in peri-urban areas. However, because the impact of factors related to individual wet market vendors are more significant than socio-economic impact factors in general, the profitable development of both urban and peri-urban food businesses depends more on wet market vendors themselves.

The findings of the study have the following implications from the perspective of three agents related to wet market vendor profit: (1) For the governments, firstly, they could provide a more enabling environment for wet market vendors, especially those in peri-urban districts, through subsiding rents and vendor expenditures. Secondly, when planning the distribution of wet markets throughout the city, planners need to consider the location, infrastructure, and proximity to consumers; Thirdly, government needs to strengthen the construction of infrastructure, especially in peri-urban areas, to complement urban food planning and increase food accessibility. (2) From the perspective of market managers, they need to train wet market vendors on business strategies to improve their competitiveness, and commit to creating a safer and more efficient wet market food environment which is suitable for community and regional demand. (3) As for wet market vendors themselves, they should adjust their business strategies flexibly

according to the demand of their communities or regions they are located in.

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