Empirical Analysis on the Mutual Substitution Relationship between Vegetables in Beijing Based on LA-AIDS Model

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Abstract. Vegetables are parts of the most important agricultural products in daily life. With the influence of season, supply and demand, the prices fluctuate greatly, and there are also some substitute linkages between different vegetables. Vegetable market is an important part for the stability of agricultural products market. But in recent years, the abnormal fluctuations in vegetable prices become more and more apparent, abnormal fluctuations in vegetable prices caused some impact not only on vegetable cultivation, but also on vegetable processing. Consumption have a certain impact on market stability. In the increasingly close relationship between different markets, the substitution between agricultural products is growing, and the price of agricultural products also penetrate each other. Other agricultural products, especially vegetables with strong substitutes, the price changes will have a certain impact on the price of alternative vegetables. This paper mainly explores the relationship between vegetable prices by explaining the relationship between different vegetable prices, explaining the theory of price fluctuation from the perspective of substitution, and also providing some reference for the analysis of the alternative relationship between different agricultural products. In this paper, we selected the daily price data of 30 representative vegetables from January 1, 2010 to December 31, 2014 in the wholesale market of Beijing, and used LA-AIDS method to analyse. The results showed that the cross price coefficient between leafy vegetables and root vegetables, cabbage, cabbage, beans, melons and fungi was positive, and there was an alternative relationship with eggplant, onion and garlic, (The elasticity of expenditure), from large to small are: leafy vegetables, onion and garlic, root vegetables, potato taro species, and so on., Eggplant, melons, sprouts, beans, cabbage, cabbage, fungi.

1. Introduction
In the mutual substitution relationship, substitute refers to one or several commodities, which can replace the function or utility of the existing goods and give consumers almost the same using experience. With the great variety of vegetables, this phenomenon is very common in vegetables. For example, the substitution existing among leaf vegetables can bring consumers the similar degree of
satisfaction, taste and nutritional value. Specific to the vegetables, the rise of some vegetable’s price will lead to the following effects: on the one hand, the consumers’ income is relatively getting smaller; on the other hand, the substitutes’ price is relatively reduced. These two effects combine to influence the consumer's demand for this kind of vegetable and its substitutes. It is also necessary to pay attention to the complementary vegetables, which need to be cooked together to meet consumer demand in aspects of taste, nutritional value, etc. Therefore, when certain vegetable price fluctuates, whether it will affect other vegetables’ prices as a substitute or complement?

Alternative commodities (Substitutes) refer to 2 or more than 2 kinds of products which have similar functions and can be replaced to meet consumers’ same needs. As a kind of food, the replacement of vegetables can be roughly subdivided into 3 aspects: nutrition substitute, flavor substitute and collocation substitute. Nutrition substitute happens mainly in leafy vegetables. For example, rape, spinach and lettuce are regarded by most people as the typical green leafy vegetables which are rich in vitamin C, and when the price of one mentioned leafy vegetable rises, consumers tend to buy other 2 leafy vegetables. Flavor substitute occurs mainly among vegetables which have certain special flavor, like Chinese green onion, onion, ginger, garlic, etc. The substitute relationship between Chinese green onion and onion is apparent. While collaboration substitute is mainly embodied in the Chinese cooking practice, in which consumers prefer to cook certain dish with fixed collaboration. For example, the combination of potato, eggplant and green pepper in a dish is a mainstream cooking practice in the north of China.

According to the edible part, vegetables can be divided into 6 categories: root, stem, leaves, flowers, fruit and fungi. Also, according to agricultural biology, vegetables can be divided into 13 types: root vegetable, Chinese cabbages, green vegetable, cabbage, mustard vegetable, yam vegetable, solanaceous fruits, allium, cucurbits, legume vegetable, aquatic vegetable, perennial vegetable and mushroom.

Besides the above mentioned 3 kinds of substitute methods (including nutrition substitute, flavor substitute and collocation substitute), there are certain alternative relations between different vegetable categories. In this paper, we have made a preliminary quantitative study on the relationship of this kind of substitution.

2. Data Sources
With comprehensive consideration of the availability and accuracy of price data and volume data of all kinds of representative vegetables, 30 kinds of representative vegetables’ daily price and volume data of Xinfadi Wholesale Market of Agricultural Products(XWMAP) was used in this paper. The sample period is from January 1, 2010 to December 31, 2014. All the data was collected by Beijing Price Monitoring center.

3. Research Methods
The methods in this section includes non-parametric statistics, LA-AIDS model.

3.1. Non-parametric Statistics
Non-parametric statistics is a branch of mathematical statistics, which can be used to describe the general distribution of a certain property or relationship without using a finite number of real parameters. Nonparametric statistics do not require the overall known distribution and estimate the overall parameters while it can get the required information from the data itself. Most non parametric statistical methods are easy to understand. Among the non-parametric statistical methods, non-parametric regression with no requesting for data distribution, strong adaptability, high robustness, high model precision, fully data driven and other advantages, can provide useful technical tools for determining the parameters of regression function (Fan, 1992).

In order to eliminate the disturbance of random factors and make the resulting curves reflect the actual economic relation between variables, this paper uses the Epanechnikov kernel weight function based on 30 kinds of vegetables’ daily price data. Epanechnikov kernel function is \( K(x) = 0.75 \times (1 - x^2) I(x) \) (in). Among them, \( I(x) \) is the indicator function. when \( x \leq 1 \), \( I(x) = 1 \), otherwise \( I(x) = 0 \). In the study, the paper takes the logarithm to the 30 kinds of vegetables’ daily turnover (log of veg
expenditure=ln(X)) to construct X axis. For each x value from January 1, 2010 to December 31, 2014, the paper calculates the proportion of each vegetable turnover to form Y axis.

3.2. AIDS Model

According to the consumption theory, rational consumers always want to be in the budget constraint to maximize the effectiveness when the income is limited. Combined with the consumer's preferences, and the existence of the interaction between different goods consumption, this paper based on the expenditure elasticity and price elasticity to calculate the substitution relationship between vegetable varieties.

The AIDS model is proposed by Deaton Angus and Muellbauer John (1980). If the consumer behavior meets PIGLOG (Independent Generalized Log) preference, which means the cost or expenditure function meets the PIGLOG type function, AIDS (Almost Ideal Demand System) can be estimated using "approximation" function method of Rotterdam Demand Model and Translog Model by extending the Woking-Leser's Engel curve model. The AIDS model helps the rational consumers to achieve the given utility level with the least expenditure in a given price system and a certain level of utility.

Based on the two order approximation of the unknown form of the utility function, The AIDS model can be more intuitive to show the impact of various variables such as price and expenditure on the consumption structure. Also, it can directly estimate almost all parameters which can explain the consumption structure. In this paper, the daily turnover of 30 kinds of vegetables is considered as consumer spending.

The general estimation form of the AIDS model is:

$$w_i = a_i + \sum_{j=1}^{n} r_{ij} \ln P_j + b_i \ln(X/P) + u_i \quad (1)$$

In the formula, $w_i$ is the proportion of vegetable of i kind in the total turnover; $P_j$ is the price of vegetable of j kind; $X$ is the total turnover; $P$ is the price index; $a_i, b_i, r_{ij}$ are regression coefficients to be estimated.

In order to keep in line with the demand theory, the equation (1) must satisfy the following requirements: homogeneous constraints, plus general constraints and symmetry constraints. For the AIDS model, the theoretical constraints can be expressed as:

Homogeneous Constraints:

$$\sum_{j=1}^{n} r_{ij} = 0$$

Plus General Constraints:

$$\sum_i a_i = 1; \sum_{j=1}^{n} r_{ij} = 0; \sum_i b_i$$

Symmetry Constraints:

$$r_{ij} = r_{ji}$$

In addition, in order to solve the estimation problem, Deaton and Muellbouer also use the Stone price index $P^*$ to replace the P:

$$\ln P^* = \sum_k w_k \ln P_k \quad (2)$$

The upper model is called the Linear Almost Ideal Demand System (LA-AIDS) Model, and the Demand Expenditure Elasticity and Demand Price Elasticity can be deduced from the model result.

3.2.1. Demand Expenditure Elasticity

Assume that different kinds of vegetable prices and total expenditure X (total turnover) are independent of each other, the elasticity ($\varepsilon_i$) of demand for i vegetable against total expenditure (total turnover) is:

$$\varepsilon_i = \frac{d \log q_i}{d \log X} = \frac{d \log w_i X}{d \log X} \frac{q_i}{p_i} = \frac{d \log w_i}{d \log X} + 1 \quad (3)$$

As a result, the Demand Expenditure Elasticity is:

$$\varepsilon_i = 1 + \frac{\beta_i}{w_i} \quad (4)$$
The upper equation means that in a certain period of time, the change of total expenditure (total turnover) to a certain extent will lead to a change of specific vegetable’s demand situation.

If the value is positive, the specific type of vegetable consumption and total expenditure (total turnover) change in the same direction. The greater the value when the total expenditure (total turnover) increased, the consumption of vegetables increased more significantly.

3.2.2. Demand Price Elasticity

The LA-AIDS model can be used to calculate the price elasticity and cross price elasticity of vegetables:

$$\eta_{ij} = -\delta_{ij} + \frac{r_{ij} - b_j w_j}{w_j}$$

When i=j, $\delta_{ij}=1$, $\eta_{ij}$ is the price elasticity. Since the value of the price elasticity is negative, it shows that the consumption and the price change in opposite direction.

When i\(\neq\)j, $\delta_{ij}=0$, $\eta_{ij}$ is the cross price elasticity. The value of cross price elasticity can be positive and negative. When positive, it indicates that the substitution relationship between the two kinds of vegetables and when negative, it indicates the complementary relationship between the two kinds of vegetables.

4. Empirical Results and Analysis

The results is in following. At first, the non-parametric curve is listed in the graph, and according to the graph, the LA_AIDS is used to establish the relative price relation between vegetables.

4.1. Non-parametric Engel Curve

The following are non-parametric Engel curves of 30 kinds of vegetables in this study. Generally speaking, The shape of the Engel curve of most vegetables can be simplified as a linear relationship between the volume of its transaction and the logarithm of the total expenditure. Therefore, this paper uses the LA-AIDS model to analyze the substitution of different kinds of vegetables in Beijing.

4.2. Empirical Results of LA-AIDS Model

The Results and Analysis of the Mutual Substitution between the 30 Kinds of Vegetables. In this paper, Stata was used to do the empirical research on the relationship between the 30 kinds of vegetables, and the results are as follows (most of the coefficients of the explanatory variables are passed by 1% and 5% of the t test. For better visibility, t test results are omitted). It is obvious to see that the diagonal line presents the price elasticity and the other elastic coefficients are cross price elasticity.

From the above model, we can see the price elasticity of 30 kinds of vegetables are all negative. It shows that if the price of vegetables decreased, the total turnover of the vegetable market will increase due to the increase in the number of purchase and that lower prices have a greater role in expanding the consumption of vegetables.

From the cross price elasticity perspective and take radish as an example, the cross price elasticity between radish and the following vegetables are positive, which means the existing of substitute relationship: onion, wax gourd (waxg), cucumber, leek, mushroom, lettuce, ginger, garlic-sprouts, rapeseed, yuancabbage, eggplant. While the cross price elasticity between radish and the following vegetables are negative, which means the existing of complementary relationship: spinach, cauliflower (cauli), cabbage, green Chinese onion (gonion), garlic, beans, yellow-bean sprouts (ysprouts), carrot, hot pepper(hpepper), bitter melon (bmelon), green-bean sprout (gsprout), celery, green pepper (gepepper), potato, wosun, xiaocabbage, tomato, leaf-lettuce. From the Chinese cooking habits, some of the above substitute/ complementary relationships have reasonable explanation. Such as white radish, onion, leek, garlic-sprouts all taste spicy and the substitute relationship do exist between them. Since white radish and pepper always salad together, there is complementary relationship between them. However, due to different taste preferences of consumers, the public health awareness to pursue nutritional balance and other factors, the substitute/ complementary relationship between vegetables is not very clear.
From the expenditure elasticity perspective, the expenditure elasticity indicates the demand changes of specific vegetable caused by the change of total expenditure (total turnover). The expenditure elasticity is greater than 0 indicates the consumption of vegetables and total expenditure (total turnover) move in the same direction. The greater the value of expenditure elasticity, the greater increase in the amount of consumption of this type of vegetables when the total expenditure (total turnover) increased. Vegetables with the top ten largest expenditure elasticity are potato (0.079), garlic (0.076), garlic-sprouts (0.066), ginger (0.063), tomato (0.062), cucumber (0.058), green Chinese onion (0.053), beans (0.046), onion (0.046), hot pepper (0.040).

Considering price, nutrition, Beijing residents’ taste preference and other factors, the calculation result is consistent with the vegetable consumption ranking in Beijing. The 10 most consumed vegetables are potato, Chinese cabbage, onion, cabbage, green Chinese onion, wax gourd, carrot, tomato, cucumber, radish.

The substitution result and analysis of 11 types of vegetables. As mentioned above, the substitute/complementary relationship between 30 kinds of vegetables is not very clear. To further clarify the substitute/complementary relationship, the paper classified the existing 30 kinds of vegetables according to agricultural biology which includes root vegetable, Chinese cabbages, green vegetable, cabbage, mustard vegetable, yam vegetable, solanaceous fruits, allium, cucurbits, legume vegetable, aquatic vegetable, perennial vegetable and mushroom. Since there are no vegetable in 30 kinds belongs to aquatic vegetable, perennial vegetable and mustard vegetable, and the yellow-bean sprouts and green-bean sprouts can be merged into buds, the paper formed 11 types of vegetables at last (see table below).

In the analysis, Stata was used to do the empirical research on the relationship between the 11 types of vegetables, and the results are as follows. It is obvious to see that the diagonal line presents the price elasticity and the other elastic coefficients are cross price elasticity.

From the above model, we can see the price elasticity of 11 types of vegetables are all negative. It shows that if the price of vegetables decreased, the total turnover of the vegetable market will increase due to the increase in the number of purchase.

From the cross price elasticity perspective and take green vegetable as an example, the cross price elasticity between green vegetable and the following vegetables are positive, which means the existing of substitute relationship: root vegetable, Chinese cabbages, cabbage, legume vegetable, cucurbits, mushroom. While the cross price elasticity between green vegetable and the following vegetables are negative, which means the existing of complementary relationship: solanaceous fruits, allium, yam vegetable, buds. It is not surprising that the green vegetable has substitute relationship with root vegetable, Chinese cabbages due to similar nutritional value, taste and flavor. In addition, due to different nutritional value, taste and flavor, and the need to cooperate with each other in cooking, it is practical that the green vegetable has complementary relationship with allium, yam vegetable and buds. In general, it is clear that there are substitute and complementary relationships between 11 types of vegetables.

From the expenditure elasticity perspective, the expenditure elasticity indicates the demand changes of specific vegetable caused by the change of total expenditure (total turnover). The expenditure elasticity is greater than 0 indicates the consumption of vegetables and total expenditure (total turnover) move in the same direction. The greater the value of expenditure elasticity, the greater increase in the amount of consumption of this type of vegetables when the total expenditure (total turnover) increased. Vegetable with expenditure elasticity’s descending arrangement: green
vegetable (1.442), allium (1.140), root vegetable (1.140), yam vegetable (1.009), solanaceous fruits (0.974), cucurbits (0.915), buds (0.880), legume vegetable (0.718), cabbage (0.641), Chinese cabbages (0.473), mushroom (0.310).

It is worth noting that the expenditure elasticity of green vegetable is far ahead of other types. On the one hand, this phenomenon shows the well-known consciousness that green vegetables are good for health. On the other hand, it shows green vegetable is the dominant vegetable variety. These judgments are in good agreement with the objective reality.

5 Conclusions and suggestions

To sum up, 11 kinds of vegetables do exist substitute, complementary relationships, while the leaf of the expenditure elasticity is far ahead of onion and garlic, root vegetables, etc., these judgments are more consistent with the objective reality. Through the relationships between vegetables, this article from the production, processing, circulation, the whole process of four aspects of the stability of the vegetable market analysis, and make appropriate recommendations.

5.1 Production links: guiding the rational planting areas

Production is the source of market stability, and strengthening the control of the production chain has critical significance to enhance the stability of the vegetable market. It can be seen from the above table, leafy vegetables are the most important vegetable varieties in daily life. The Price elasticity of leafy vegetables is 1.442, and it is also the most flexible spending for all vegetables. So in short term, the higher price of leafy vegetables will make the root vegetables, cabbage, beans, melons, fungi have more consumption. In the long run, the changes of supply and demand make the market price of these types rise, and that could make the next cycle have more supply just as cabbage, beans, melons, fungi. In the total expenditure of consumers under the same conditions, it can eventually make these types of agricultural products prices fall sharply in the next cycle, and that could make the next cycle have more supply just as cabbage, beans, melons, fungi. In the total expenditure of consumers under the same conditions, it can also make some loss to farmers as well as market price imbalance. So the government should strengthen macro-control to ensure that leafy vegetables and other vegetable have their own stable planting area, and it is essential for the overall stability of the vegetable market.

5.2 Processing links: emphasizing vegetable processing

Processing could not only adjust the supply and demand of vegetables but also enhance the added value of vegetables, and it is also an important part of increasing income for farmers. Vegetable processing is the final link to the hands of consumers, and it plays an important role to protect the vegetable market more stable. From the above table: the cross-price coefficient of leafy vegetables and root vegetables, cabbage, beans, melons, fungi are positive, it means there is an alternative relationship; the cross price coefficient of eggplant, onion, garlic potato, and seedling are negative, and it means there are complementary relationships. When the supply of leaf vegetables increases, we should pay attention to the processing of alternative vegetables such as root vegetables, cabbage, beans, melons, fungi and so on. When the supply of leaf vegetables reduces, we should pay attention to the processing of relevant vegetables such as eggplant, onion and garlic, potato taro, sprouts. The relevant departments can also adjust the supply and demand of vegetable through the processing.

5.3 Circulation: stabilizing the consumption of major vegetables (leafy vegetables)

The greater value of the expenditure elasticity, there will be the greater increase in the consumption of the vegetable. If the expenditure elasticity is greater than 1, it means the increase in the consumption of vegetables is more than the total expenditure increase. And if the expenditure elasticity is less than 1. It means the increase in the consumption of vegetables is less than the increase of the total expenditure. The vegetables with the elasticity greater than 1 are: 1.442), onion and garlic (1.140), root vegetables (1.140). In the circulation, the government should adjust the vegetable prices according to the change of the disposable income of the residents. That could avoid the increase of the consumption of these vegetables and the increase of the consumption of the other vegetables, and it could also stabilize the consumption of the main vegetables.
5.4 The whole process: strengthening the early warning of vegetable market

Early warning refers to the timely and effective forecast before the disaster. It is also used in the monitoring of agricultural price. As an important tool to maintain the stability of the agricultural market, the early warning can play an important role. Vegetable market early warning should be mainly used for several major categories of vegetables, such as: leafy vegetables (1.442), onion and garlic (1.140), root vegetables (1.140), potato taro (1.009), etc. Through the monitoring of main vegetable varieties, it can achieve the vegetable market more stability not only in price but also production, processing and circulation.

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