A study on the correlation of cyclical fluctuations in vegetable commodity sales based on wavelet analysis modeling

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Abstracts. As the sales volume and time of vegetable commodities tend to have a certain correlation, in order to explore the distribution law of the sales volume of each category and single product of vegetables, this paper firstly handles the data to get the monthly sales volume of each vegetable category and single product of time series data, then uses Matlab's Wavelet Toolbox to carry out wavelet analysis, drawing wavelet variance diagrams, the main cycle trend graph to judge the cyclical pattern of each vegetable category and single product, and then use Origin to make wavelet coefficients real part contour graph to verify the law, and finally get the distribution law. This study can help superstores better grasp the sales situation and development trend of each vegetable category and single product.

Keywords: Vegetable Commodity, Characteristics of sales fluctuations, Wavelet analysis.

1. Introduction

In fresh food superstores, fresh vegetables are the most consumed food by Chinese consumers, much higher than the consumption of other fresh food commodities, which leads to frequent purchasing behaviour by consumers, so fresh food superstores use the operation of fresh vegetables as a "source of attraction" to attract consumers[1]. Vegetables circulate between production and consumption, and the vegetable market plays a strong link between vegetable production and consumption, becoming an important link in regulating the balance between supply and demand, with an irreplaceable role[2]. Primary products such as meat, aquatic products, fruits and vegetables, which are usually not deeply processed and cooked, are collectively referred to as fresh food. The common point of fresh food is that it has a shorter shelf life and is susceptible to corruption and deterioration under normal temperature conditions[3]. Most vegetable varieties that are not sold on the same day will not be purchased by customers the next day due to lack of freshness. As a result, superstores usually restock daily based on historical sales and demand for each item. In order to rationalise the replenishment strategy and pricing strategy, the relationship between merchandise category and sales volume needs to be explored. At present, domestic and foreign use of wavelet analysis on different categories of fresh vegetables sales distribution law to explore the literature is relatively small, most of the literature is focused on the sales of vegetables to predict and analyse the factors affecting the sales of vegetables, and the distribution of sales of vegetables of different categories of the law is not explored. As Lü Wang suggests, fresh vegetables are susceptible to seasonal changes that can affect[4]. As well as Haoxu Yang also mentioned in his article that each vegetable has its corresponding seasonal characteristics[5]. However, most of the literature has not examined the sales distribution pattern of vegetables, so this paper will explore that aspect. Based on the method of Xiaohan Zhang, Lidan Wang, and Yinghao Liu using Morlet wavelet analysis, the annual mean precipitation time series of Weifang City from 1955 to 2020 were characterised by multi-timescale variations[6]. This method is also applicable to the problem of exploring the distribution law of fresh vegetables sales volume, so this paper, for the sales volume time series, adopts the technique of Morlet wavelet analysis to explore the time-varying characteristics of the monthly sales volume series of the superstore's fresh vegetables from 2020 ~ 2023, and to excavate the fluctuating changes in the sales volume of different categories of vegetables. Wavelet analysis is then performed on each vegetable item, from which the vegetable item with the highest number of sales is selected and its distribution pattern is analysed.
2. Overall idea

In order to find the distribution pattern of the sales volume of vegetables by category and individual product, firstly, this paper preprocesses the monthly sales volume series data of fresh vegetables from 2020 ~ 2023. Secondly, the method of wavelet analysis is used to find the periodicity pattern of the sales volume time series, and the wavelet coefficients are obtained by using Matlab's Wavelet Toolbox, and then the real part of the wavelet coefficients, the mode, the mode square and the variance are calculated. Finally, this paper draws the wavelet variance diagram, the main cycle trend diagram and the real part of the wavelet coefficients contour plot to analyze the distribution pattern of different vegetable categories and single products, in order to help the superstore better grasp the sales status and development trend of each category and single product, the article lineage is shown in Figure 1.

![Figure 1. Article lineage](image)

3. Preparation of the model

“http://www.mcm.edu.cn/html_cn/node/c74d72127066f510a5723a94b5323a26.html.” is the data source for this article.

Data Preprocessing: 1. Add the vegetable category data because we want to analyse the vegetable category. 2. Process the return data (negative data) and assign the negative data to 0, which means that the product was not successfully sold on that day. 3. Calculate the monthly sales of each vegetable category and individual product.

4. Model building

The basic idea of Morlet wavelet analysis is to represent or approximate a signal or function by a family of clustered wavelet functions.[7] By decomposing the time series in time-frequency space, one is able to identify the main patterns of change and how these patterns vary in the time dimension[8]. Vegetable sales are affected by various cyclical and non-cyclical factors such as climate, price, consumer preference, policy, etc. The time series is non-linear, non-smooth and has multi-timescale characteristics, so it is very meaningful to use wavelet analysis to analyse the vegetable sales series at multi-timescales and to dig out the distribution pattern[9].

Morlet wavelet is the most commonly used complex-valued wavelet function, and its wavelet transform graph can easily see the periodic characteristics of the spatio-temporal variation of physical quantities, which is suitable for the study of different spatio-temporal levels of the structure of the signal[10]. The Morlet wavelet basis function expression is shown in Equation (1), which consists of a complex trigonometric function multiplied by an exponential decay function, where $\omega_0$ denotes the centre frequency. In this question, Matlab's Wavelet Toolbox is used to perform Complex Continuous Wavelet 1-D analysis of the data and draw the real part contour plots of the wavelet coefficients and wavelet variance plots to find out the pattern of the monthly sales of different vegetable categories and individual products.
5. Solution of the model

In this paper, we first use Excel to draw a graph of monthly sales fluctuations in the vegetable category, here using eggplant and aquatic roots and tubers as examples. Based on Figures 2 and 3, it was found that both types of vegetables showed seasonality in sales trends, with peaks occurring in November and March. In particular, sales of eggplant vegetables fluctuated over a narrower range, suggesting a more stable demand for these vegetables throughout the year, while sales of aquatic root vegetables were more sensitive to changes in volume, with more extreme month-to-month changes in volume.

Next, the monthly sales data for each vegetable category was extended using Matlab's Wavelet Toolbox, and here a symmetric extension was used. The extension is to eliminate boundary effects and to make the results of the analyses at the front and back boundaries more accurate. The wavelet coefficients are then calculated using the Complex Continuous Wavelet 1-D method, where the front-to-back symmetric delayed data are deleted, and then the real part of the wavelet coefficients are calculated using Matlab's real function, and the ads function calculates the mode, the modulus, the modulus square, and the variance.

Finally, wavelet variance plots, main period trend plots and contour plots of the real part of the wavelet coefficients were drawn using Excel and Origin to analyse the time series data. The wavelet variance reflects the distribution of the energy of the fluctuations with scale $a$. It can be used to determine the relative strengths of various scales of perturbations in a time series, and the scale at the corresponding peak is called the characteristic time scale of the series. Referring to Figs. 4 and 6, this paper draws wavelet variance plots with eggplant and aquatic rhizomes as examples, and finds that three peaks appear in Fig. 4, i.e., September, 18, and 55 months as the main cycle of the sequence; Four peaks appear in Figure 6, in September, 17, 35 and 57 months. In this paper, the first main cycle, i.e., 18 months and 17 months, is extracted for graphing to better represent the cyclical characteristics of monthly vegetable sales. The following conclusions are obtained from Figures 5 and 7:

In terms of oscillatory phase, there is a significant phase difference of about 6 months between eggplant and aquatic rhizomes. On an 18-month time scale, the period of eggplant is 11 months, and on a 17-month time scale, the period of aquatic rhizomes is 12 months, suggesting that the two vegetables are subject to different seasonal influences.

In terms of volatility, sales of solanaceous vegetables were relatively less volatile, suggesting relatively stable market demand, whereas aquatic root vegetables were more volatile, implying that their market demand might be more volatile.
The real part of the Morlet wavelet coefficients exhibits information about both the distribution of signals on different characteristic time scales at different times as well as the phase of the bit. Positive wavelet coefficients reflect that the analyzed object is a biased period in that time period, while negative values reflect a biased period, and zero values correspond to mutation points [9]. The horizontal coordinates of the real part of the wavelet coefficient contour plots represent moments and the vertical coordinates represent time scales, and Figure 8 illustrates a series of concentric circle shaped contours that are centered on peaks in the color variations, which represent the periods of strongest energy in the cyclical fluctuations of the sales data. The presence of a cyclical pattern on a time scale can be seen from the recurrence of concentric circular patterns, and in particular, a clear cyclical pattern can be observed in the region with a time scale of about 20 months, which suggests that there is a significant cyclical fluctuation in the monthly sales of eggplant vegetables over an 18-month cycle. Similar to Figure 8, the strong centroids of color variations and the contours surrounding them in Figure 9 reveal the cyclical nature of sales of aquatic root vegetables. The cyclic pattern formed by these contours is more pronounced and concentrated on the time scale than the cycles of eggplant vegetables, especially on the 17-month cycle. From Figures 8 and 9, it can be seen that the sales of these vegetables have significant peaks and troughs in each cycle, showing a strong cyclical pattern, which further supports the above conclusion that the main cycle of the two vegetables is 18 and 17 months, showing a significant cyclical pattern, with a cycle of November and December, respectively.
Figure 8. Contour map of the real part of the wavelet coefficients of the aubergine

Figure 9. Contour map of the real part of the wavelet coefficients of the Aquatic rhizomes

By performing wavelet analysis for each vegetable category, the following pattern was obtained (see Table 1):

1. **The sales volume of vegetable categories has some cyclical changes.** The main cycle of sales of leafy flowers and peppers is 26 months, that of cauliflower is 27 months, that of edible mushrooms is 18 months, that of eggplants is 18 months, and that of aquatic roots and tubers is 17 months.

2. **The sales volume of foliage, cauliflower, pepper, edible mushrooms, eggplant, and aquatic roots and tubers maintain relatively stable fluctuations over the cycle.** The sales volume of eggplant has a cycle of 11 months, the sales volume of edible fungi and aquatic roots and tubers has a cycle of 12 months, the sales volume of foliage has a cycle of 17 months, and the sales volume of cauliflower and chili peppers has a cycle of 18 months. The cycle of these vegetable categories changes steadily, and the length of the cycle does not fluctuate significantly over time, which provides a more reliable basis of forecasting for agricultural producers and retailers.

<table>
<thead>
<tr>
<th>vegetable category</th>
<th>main cycle</th>
<th>Whether there is a cyclical pattern</th>
<th>cyclicality</th>
<th>Changes in the cycle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florifolias</td>
<td>26 months</td>
<td>Yes</td>
<td>17 months</td>
<td>stability</td>
</tr>
<tr>
<td>Flower vegetables</td>
<td>27 months</td>
<td>Yes</td>
<td>18 months</td>
<td>stability</td>
</tr>
<tr>
<td>Capsicum</td>
<td>26 months</td>
<td>Yes</td>
<td>18 months</td>
<td>stability</td>
</tr>
<tr>
<td>edible fungi</td>
<td>18 months</td>
<td>Yes</td>
<td>12 months</td>
<td>stability</td>
</tr>
<tr>
<td>eggplant</td>
<td>1 months</td>
<td>Yes</td>
<td>11 months</td>
<td>stability</td>
</tr>
<tr>
<td>Aquatic rhizomes</td>
<td>17 months</td>
<td>Yes</td>
<td>12 months</td>
<td>stability</td>
</tr>
</tbody>
</table>

6. **Conclusions**

In this study, the characteristics and patterns of cyclical fluctuations in vegetable commodity sales are explored in depth by applying the multi-resolution analytical properties of wavelet-analysis. The study finds:

1. **Recognition of cyclical fluctuations:** Monthly sales data for the vegetable category show significant cyclical fluctuations, indicating a cyclical pattern of sales activity in the vegetable market.

2. **Identification of cycles:** Different vegetable categories have different cycles ranging from 11 to 18 months, which may be related to factors such as biological growth cycles, market supply and demand, and seasonal consumption patterns.

3. **Observation of cyclical stability:** All the studied categories show stable fluctuation trends within their respective cycles, emphasizing the potential value of cyclical forecasting in supply chain management.
4. **Comparison of volatility trends:** While the categories exhibit cyclical fluctuations, the magnitude and trends of the fluctuations vary, reflecting differences in consumer preferences and market availability across categories.

5. **Gradual change in market demand:** Some categories, such as aquatic root vegetables, show a gradual trend of increasing demand, suggesting a long-term shift in consumer preferences.

6. **Practical applications of sales forecasting:** These cyclical patterns provide supermarkets and agricultural producers with important information for sales forecasting, which helps to optimize inventory management and production planning.

   This paper not only enriches the literature on the cyclicality of fresh vegetable sales, but also provides an empirical basis for the optimization of superstore management and agricultural production plans. Future research can further explore the relationship between cyclical fluctuations and external factors (e.g., climate change, holidays, and promotional activities) to more accurately guide production and sales decisions.

### References


