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Analysis for Time Series Trend and Change Point of Chinese Food Poisonous Incidents Based on SARIMA Model

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Food safety risk pre-warning is an important part of food safety management. Food poisoning incidents (FPI) is one of the important index to measure the food safety. By establishing SARIMA model, this paper conducts time-trend analysis of Chinese food poisoning incidents, makes relevant forecasting and change points detection, in order to provide reference and data support for the related research on the Chinese food safety pre-warning. During the analysis of change points, Bayesian detection method is applied to determine the time of structural break in the time series: Nov 2009, Mar 2011, and Feb 2013 respectively, which shows that some related policies by the government haven't achieved an ideal effect, and the measures regarding the food safety require further improvement and intensified implementation.

1. Introduction

Food safety risk pre-warning is an important part of food safety management. Food poisoning incidents (FPI) is one of the important index to measure the food safety. Some scholars at home have started to emphasize on and make focused empirical studies of such issues as how about the time-trend of Chinese poisonous incidents? Whether seasonal factors are involved? Whether being influenced by the laws and regulations or the major food safety incidents (Wang et al., 2016; Fattahi et al., 2017), by analysing the related information of 766 bacterial poisoning cases in 1994-2003, concluded the main occurrence areas and places for one certain kind of bacterial FPI, but it was in lack of comprehensiveness, because only bacterial food poisoning cases were studied. (Qi et al., 2009), adopted ARIMA model to study empirically the food poisoning data in 1992-2001 in Zhejiang Province, and forecast the food poisoning death toll; while (Zhang and Fan, 2012) also applied the ARIMA model to make dynamic analysis and forecasting of national food poisoning incidents; both adopted the ARIMA model for time series analysis of FPI, but the former only focused on Zhejiang Province, excluding the others provinces in China, and the latter ignored the seasonal factors. Therefore, this paper, by establishing SARIMA model, conducts time-trend analysis of Chinese FPI, makes relevant forecasting and change points detection, in order to provide reference and data support for the related research on the Chinese food safety warning.

2. Data source

This paper has selected the monthly data of Chinese FPI occurrence number for the time series analysis, because the reliability and manoeuvrability of empirical results are closely related to sample size. In terms of data accessibility and consistency, the related data of Chinese FPI from Jan. 2004 to Dec 2013 were selected for empirical analysis. To ensure the sample certainty, the data in this paper was mainly sourced from the related statistics data and bulletins of Ministry of Health.

3. Time-trend analysis of Chinese food poisoning incidents

Figure 1 depicts the time trend graph for occurrence number (X) of Chinese FPI, indicating the main features of these incidents: firstly, Chinese FPI every year shall have the time point with intensified break, rather than mild changing trend; it presents periodic fluctuation, without a stably increasing or decreasing trend as a whole; but compared with that in 2006-2008, the occurrence number of incidents has decreased obviously

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since 2010. Furthermore, the occurrence of FPI is mainly centred in June-Sep in Summer-early autumn, presenting an obvious seasonal trait. During this period, the main reasons for heavy occurrence of such incidents include: 1) Higher temperature; the food with higher time-requirements also has higher demands for storage condition, and any improper storage might easily lead to food spoilage, further causing food poisoning incident; 2) Weather condition; due to the weather conditions, the people often eat out, so as to increase the probability of FPI occurrence; 3) Sidewalk stands or food stall are popular during this period; compared with the restaurants, they are much cheaper, but with limited profit margin, so without effective supervision, the vendors sell shoddy food, or even uses inferior food material, easily resulting in food poisoning incidents.

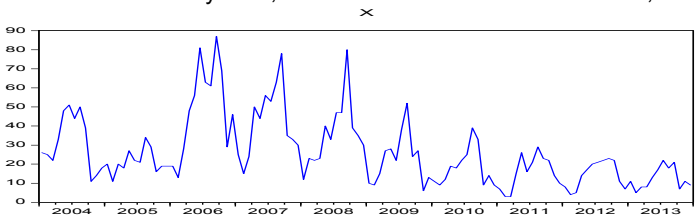
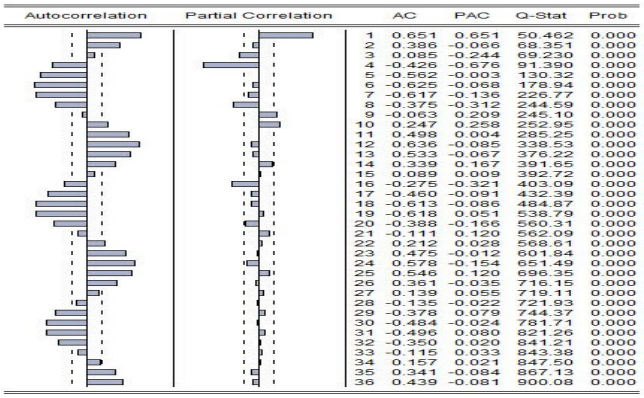


Figure 1: Time-trend graph for occurrence number of Chinese food poisoning incidents

To determine the time series stability for FPI, the unit root test was made, to obtain the P value 0.0024, and strongly reject the null hypothesis of the original series, so the original series was listed as stationary series. Considering the obvious seasonal trait, the series should be adjusted seasonally.

4. SARIMA model for Chinese food poisoning incidents

Figure 2 shows that partial autocorrelation function of X (occurrence number of FPI) truncates in 1-order lag and 4-order lag, and it starts to decrease in lag 4-order, indicating the moving average process of low order. Also, series X has 4-cycle seasonal changes, so it is necessary to make 1-order seasonal difference processing, and the results are shown in Figure 3.



	AC	PAC	Q-Stat	Prob
1	0.651	0.651	50.462	0.000
2	0.386	-0.066	68.351	0.000
3	0.085	-0.244	69.230	0.000
4	-0.426	-0.676	91.390	0.000
5	-0.562	-0.003	130.32	0.000
6	-0.625	-0.068	178.94	0.000
7	-0.617	-0.136	226.77	0.000
8	-0.375	-0.312	244.59	0.000
9	-0.063	0.209	245.10	0.000
10	0.247	0.258	252.95	0.000
11	0.498	0.004	285.25	0.000
12	0.636	-0.085	338.53	0.000
13	0.533	-0.067	376.22	0.000
14	0.339	0.167	391.65	0.000
15	0.089	0.009	392.72	0.000
16	-0.275	-0.321	403.09	0.000
17	-0.460	-0.091	432.39	0.000
18	-0.613	-0.086	484.87	0.000
19	-0.618	0.051	538.79	0.000
20	-0.388	-0.166	560.31	0.000
21	-0.111	0.120	562.09	0.000
22	0.212	0.028	568.61	0.000
23	0.475	-0.012	601.84	0.000
24	0.578	-0.154	651.49	0.000
25	0.546	0.120	696.35	0.000
26	0.361	-0.035	716.15	0.000
27	0.139	0.055	719.11	0.000
28	-0.135	-0.022	721.93	0.000
29	-0.378	0.079	744.37	0.000
30	-0.484	-0.024	781.71	0.000
31	-0.496	0.080	821.26	0.000
32	-0.350	0.020	841.21	0.000
33	-0.115	0.033	843.38	0.000
34	0.157	0.021	847.50	0.000
35	0.341	-0.084	867.13	0.000
36	0.439	-0.081	900.08	0.000

Figure 2: Correlation diagram of X (occurrence number of Chinese food poisoning incidents)

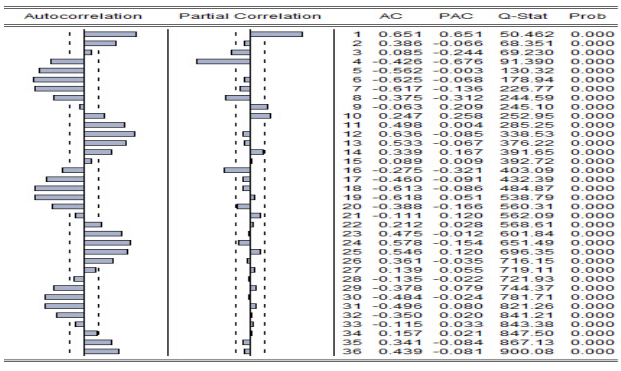


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Figure 3 Correlation diagram of 1-order seasonal difference series (SX) for original series (X)

In Figure 3, the partial autocorrelation function truncates in lag order 1, order 3 and order 4, and the partial autocorrelation of X (see Figure 2) started to decrease in lag order 2, indicating the moving average process of low order.

Above all, the (4,0,1) × (1,1,1) $_4$SARIMA model was established for X. The model estimate results are shown in Table 1:

Table 1: Analysis results of SARIMA MODEL

Variable	Coefficient	Prob.
C	-0.527642	0.6470
AR(1)	0.524575	0.0000
AR(2)	0.212622	0.0851
AR(3)	0.218299	0.0177
AR(4)	-0.679828	0.0000
SAR(1)	0.434178	0.3138
MA(1)	0.115673	0.6637
SMA(1)	-0.643026	0.0212
R-squared	0.727363	
Durbin-Watson stat	1.961164	

Table 1 indicates R^2 value is 0.72, showing higher goodness of fit for the whole; DW value 1.96, very close to 2, indicates no correlation for residual series. Therefore, the estimating equation is calculated as:

$$(1-0.5246L-0.2126L^2-0.2182L^3+0.6798L^4)(1-0.4342L)(1-L^4)X_t=-0.5276+(1+0.1157L)(1-0.6430L)\varepsilon_t \quad (1)$$

In Figure 4, the sample forecasting is made for X by SARIMA model, where deviation value is 0.09 between 0-1, meaning the better forecasting result, so as to testify the model feasibility.

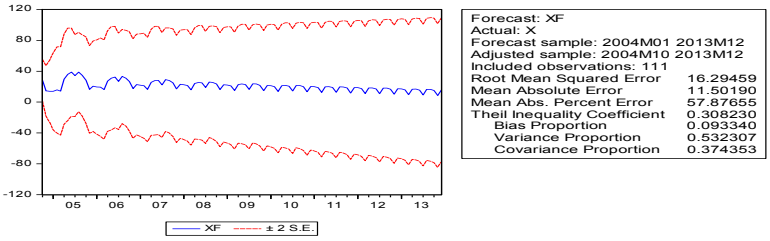

Figure 4: Sample forecasting results for occurrence number of Chinese food posioning incidents

5. Time series change point detection for occurrence number of Chinese food poisoning incidents

The domestic and overseas scholars all agrees on that Chow test is the mainstream of change point test; Chow (1960) firstly found the structural break points, took it as the given condition, estimated residual and formed F-statistics by simple least square method, so as to detect whether structure break happens in this point. But for the time series difficult to be found in advance, the scholars at home and abroad prefer to apply Bayesian detection method of change points, which cannot only help to find the change points, but also acquire the probability density distribution of change points [4]. This paper, based on Bayesian detection method, applies the MATLAB software to make analysis of the time series for the FPI in Jan 2004-Dec 2013. The results are given in Figure 5.

Figure 5 depicts the time of structural breaks: Nov 2009, Mar 2011 and Feb 2013 respectively. Besides the quality issue for the food itself, the occurrence of FPI is also influenced by some certain policy or events, reflecting the structural breaks of time series in the statistical data. For the three time-nodes above, the related incidents can be concluded: the toxic-arsenic products by Nongfu Spring and Uni-president enterprises in Nov 2009, clenbuterol incidents of Shuanghui Group in March 2011, and listing of China Food and Drug Administration in Mar 2013.

Compared with “arsenic incident” and “clenbuterol incident”, it seems that the “Sanlu milk powder” incident exposed in Sep 2008 had more serous influence, but the data analysis shows no structural break of time

series in the time node (Sep, 2008), which indicates that the “Sanlu milk powder” incident haven’t exerted a substantial influence on the FPI or occurrence of food quality safety incidents, though it had huge impact. Maybe this incident only enhanced the public’s attention to the quality safety of dairy products, but not attracting their attention to the food quality safety wholly. i.e. the occurrence of such incident didn’t have effect on promoting the government to strength the food safety supervision and booster the safety consciousness of the public. Before the “Sanlu milk powder” incident completely appeasing, the following “Arsenic incident” and “Clenbuterol incident” strengthened the emphasis of the people on food quality safety issue, so as to structurally decrease the occurrence of FPI.

Before listing of China Food and Drug Administration in Mar 2013, a large amount of publicity and reports were made by the media, both reminding the public of the importance of food quality safety and urging the food producer and manufacture to regularize behaviour and lift quality in the serious situation, therefore, structural breaks happen in time series for the food quality safety incidents in Feb 2013. Besides, the main related measures by the government included the implementation of *Food Safety Law of the People’s Republic of China* and establishment of the State Council Food Safety Commission, but no structural breaks happened in June 2009 and Feb 2010, indicating that in terms of the index “occurrence number of FPI”, these measures haven’t produced an effective result, and the measures regarding the food safety require further improvement and intensified implementation.

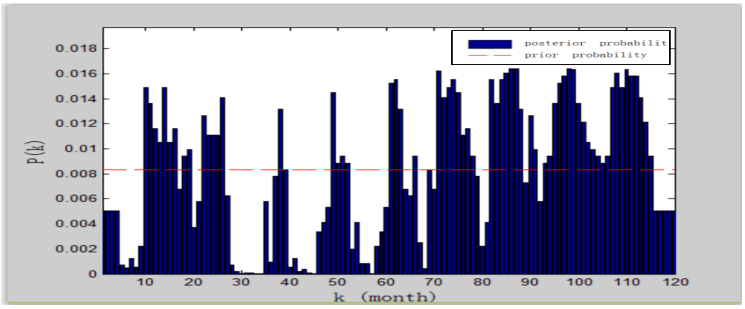

Figure 5: Probability distribution diagram of change points for the food poisoning incidents in Jan 2004-Dec 2013

6. Situation analysis for food poisoning incidents in different dining locations and with different poisoning reasons

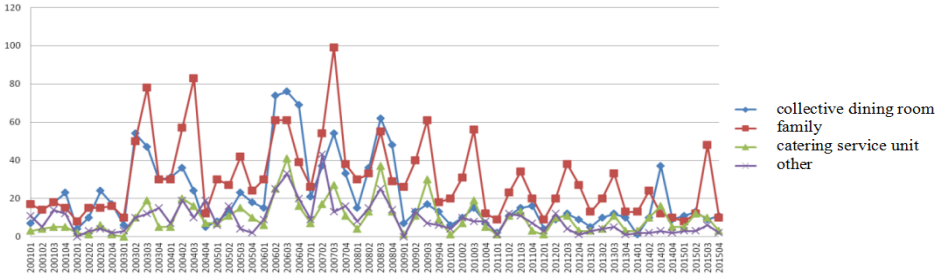

Figure 6: Trend chart of poisoning report quarterly data in different dining locations

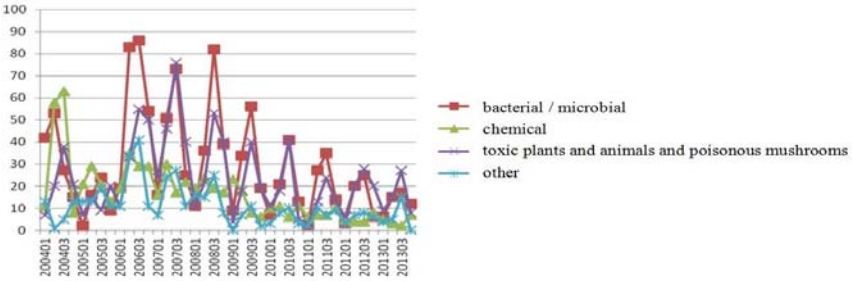

Figure 7: Trend chart of poisoning report quarterly data with different reasons

According to the classification standard of Ministry of Health in the food poisoning report, the dining locations where the FPI occur are classified into: collective canteen, household, catering service unit and others. In Figure 6, it can be seen that the collective canteen was the hotspot for food poisoning incidents over the two periods: the first quarter of 2007, and the 2nd-4th quarter of 2008; in the other periods, the most frequently-occurred locations were the household, and the collective canteen came in second, where only in the periods (in the first quarter of 2009 and the fourth quarter of 2010), the occurrence of FPI was slightly higher than the collective canteen. Based on the analysis for Figure 6, the following conclusion could be made: firstly, household is the main location where the FPI occur. Why did it occur the most in household as the safest place? Although the household can be safe and reliable in terms of cooking method, cooking oil usage and seasoner etc., the raw material for cooking cannot be self-supplied, and needs to be purchased, so it can be judged that the factors leading to unsafe food are mainly in the supply chain of raw materials, and the excessive residue of veterinary drugs, bad raw-food material, illegal food additives and logistics factor etc. are the key reasons of household FPI and then the frequent occurrence of national food poisonous incidents, which urges the Chinese food safety supervision administration to strengthen management in the food supply and logistics; secondly, the FPI in the catering service units started to decline obviously in the third quarter of 2008, indicating that food safety supervision of Chinese government for the catering service unit produced an effective result; finally, as a whole, the FPI present the decreasing trend, but in the household and collective canteen, it decreases slowly and unobvious, indicating that the Chinese administration should enforce the food safety supervision on the food sources in these two locations.

By analysing the reasons for Chinese FPI, this paper classifies the poisonous reasons into different types such as bacterial/microbial erodent, chemical, toxic plant and animal/poisonous mushroom, and others. It can be seen in Figure 7, in the first quarter of 2004 and the fourth quarter of 2005, the chemical is the main reason for Chinese food poisonous incidents, while the number of incidents caused by bacterial/microbial erodent and toxic plant and animal/poisonous mushroom are almost the same. In the first quarter of 2005 and the fourth quarter of 2013, bacterial/microbial erodent keeps a leading position among all reasons, but only in the first quarter of 2012 and 4th quarter of 2013, closely followed by the reason “toxic plant and animal/poisonous mushroom”. By analysis of Figure 7, the following conclusions could be made: bacterial/microbial erodent is the main reason for Chinese FPI, which mainly happens in the food storage and logistics links, because the storage and logistics with improper or insufficient supervision shall lead to the spoilage of food or food material, and reduce the food safety quality, then resulting in the occurrence of unsafe incidents, therefore, the food safety issue should be handled in the aspects of storage and logistics; besides, based on the later-period samples, number of FPI caused by toxic plant and animal/poisonous mushroom has increased in recent years, by comparing with other reasons, showing that the people have no complete and clear understanding of toxic plant and animal/poisonous mushroom, and the government should enhance publicity through various channels and strengthen related management.

7. Conclusions

Food poisonous incident (FPI) is one of the key index for food safety. Based on the analysis above, the Chinese food safety supervisory system and measures haven’t exerted an effective influence on this important index, which requires further improvement and promotion. Food safety issue severely impairs the public health, also hinders the Chinse food industry and the development of related foreign trade [5]. Hence, the effective measures and policies should be taken to gradually reduce the unfavourable effect of food safety issue on the society and economy:

Further improve the *Food Safety Law of the People’s Republic of China:* For different food industries and food categories, subdivide the penalty type of food safety, and then effectively promote the rule performance according to their respective characteristics; besides, enhance the punishment intensity for illegal vendors, and contain the occurrence of food safety incidents in the food supply source. In terms of regulation implementation, it is necessary to fulfil the “clear rights and responsibility, fair penalties and rewards” by strengthening law enforcement, and refining the executive section, in order to seriously treat the misconduct and intensify the law enforcement;

Strength Chinese food safety supervision mechanism and improve the food safety supervisory system: clarity the responsibility for both China Food and Drug Administration and local supervisory administration, to ensure that the higher authority makes overall coordination and supervision for the lower administration, while the lower administration has transparent feedback channels to the higher authority, thus, the work performance of supervisory administration can be improved wholly; besides, further carry on the responsibility investigation of major food safety incidents, and make “zero tolerance” for major food safety incidents by fulfilling “one-vote veto”;

Enhance the supervision and enforcement for the food raw material supply, so as to effectively reduce the occurrence of food poisonous incidents in households and collective canteens: subdivide the safety standard of food raw material and make supervision in terms of different standards; besides, take measures to promote the related laws and regulations to improve the safety supervision for food storage and logistics, strengthen the penalty of the related food safety, and reduce the occurrence ratio in the storage and logistics link;

Fully mobilize the publicity and supervision function of the mass media and public opinion: on the one hand, by the extensive publicity of mass media, improve the public's precaution consciousness and judgment for unsafe food; with the illegal enterprises, vendors and problematic food exposed by the mass media, broaden the food relation information source and reduce the damage on the public health and benefit caused by the information asymmetry in food industry; on the other hand, as the powerful device for supervision by public opinions, the mass media has an un-negligible function, so it is necessary to make full use of the mass media to prevent the food safety incidents with both legal supervision and public supervision.

Acknowledgments

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