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Cycle Phase Identification and Factors Influencing the Agricultural Commodity Price Cycle in China: Evidence from Cereal Prices

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Abstract

Agricultural commodity prices in China have undergone substantial fluctuation with the recent commodity boom and global financial crisis, which have revealed some special characteristics of cyclical change under China's transitional economy. First, this paper identifies phases of the price cycle variation using the Bry-Boschan algorithm based on price data for cereals in China. Then, the factors influencing the duration of the price cycle are analysed using survival analysis models, and the average duration of cyclical change is also measured. Finally, conclusions and closing remarks are presented for policy-makers who wish to avoid agricultural commodity price risks and improve agricultural early warning systems.

Keywords: Identification; Cyclical change; Cereal prices; Survival analysis

1. Introduction

Cereal prices not only influence farmers' income levels directly but also have direct and indirect effects on the consumption expenditure of urban and rural residents and even endanger social stability. Identifying the characteristics of the cyclical fluctuation of cereal prices enables people to develop accurate macroeconomic descriptions of cereal price tendencies, grasp the rules of cereal price variations, and provide a quantitative basis for national macro-control and policy-makers.

The structure of supply and demand for China's cereals is in transition, shifting under the impact of various emerging factors. On the one hand, cereal demand is facing the pressure of the increase in the total population and the demand created by biofuel production as well as that of structural changes in food consumption. On the other hand, cereal supply is subject to the constraints of natural resources and climate. Against this backdrop, the fluctuation in cereal prices reveals a new feature. The rate of change during the period 1997-2009, as displayed in

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Figure 1, shows that the general volatility of cereal prices has been intensifying. Examining different cereal prices, one can see large differences in the amplitude of the fluctuation, with that of soybeans being the biggest and those of mixed wheat and early indica rice being relatively small. Meanwhile, the price of crude oil (UK Brent) is likely to become more and more significant as influencing cereal price volatility in both traditional and new ways in the process of cereal price volatility. The upsurge in oil prices will not only increase the costs of cereal production, transportation and storage but also increase the processing demand for cereal with the expansion of demand for biofuels, ultimately boosting cereal prices. If the cycles of cereal prices and their influencing factors, such as crude oil price, are effectively identified, we can have a far-reaching impact on the evasion of cereal price risk. Indeed, this is our motive for conducting empirical research on the phases of the cereal price cycle.

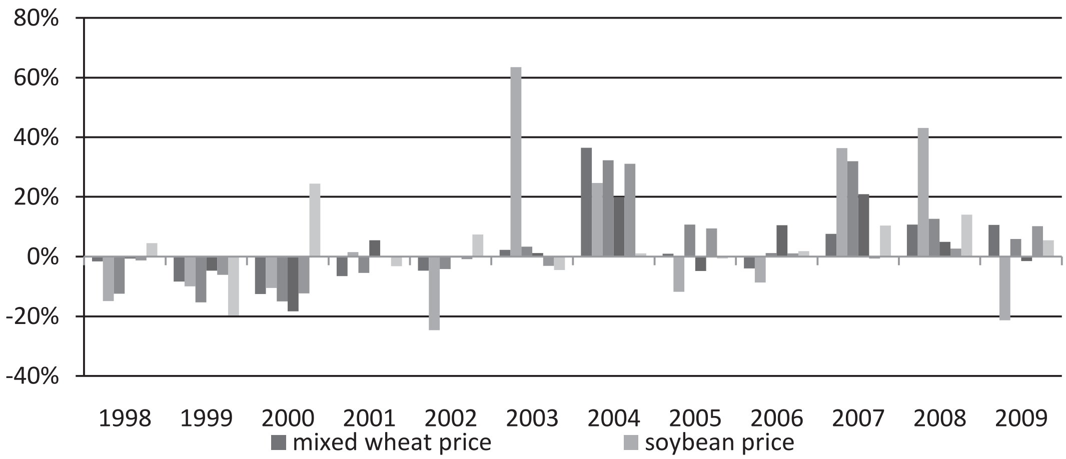

Figure 1 The rate of change of China's cereal prices year-on-year

In studies of price cycle identification or bumps and slumps, the Bry-Boschan algorithm has been applied widely (Paul Cashina et al., 2002[1]). More generally, in research on price volatility among agricultural products in China, other methods have generally been adopted, such as the use of the H-P filter， X-11 seasonal adjustment and time-series decomposition to adjust the seasonal factors and tendencies of price data (Xiaohui Guo, Dangqiao GE, 2009[2]; Xuefeng Mao, Yinchu Zeng, 2008[3]; Peng Li, 2008[4]). In one study of the cereal price cycle, a statistical indicator is used to divide fluctuations in wheat prices into five cycles over the period from January 1993 to September 2006, with the length of the cycles ranging from 29 months to 49 months (Cao Hui, 2007[5]). However, there have been no empirical analyses conducted of the influencing factors of cereal price cycles. Thus, no studies have characterised the price cycle for China's cereal using the Bry-Boschan method.

Survival analysis is one of the effective methods of analysis for time intervals and has been widely adopted. In the very beginning, it was used in the fields of industrial engineering, biological sciences, and marketing and tourism (Ummuhan Gokovali, Ozan Bahar, Metin Kozak, 2006[6]). Lately, its applications have expanded to social science fields, including in the exploration of issues such as marriage length, tenure of office among congressmen, the duration of legal cases, the lifecycle of products and firms, spacing of births, time to adoption new technologies, time between trades in financial market, spacing of purchases of durable goods, duration of wars, time between moves (Kiefer, 1988[7]). So far, survival analysis has been used to analyse the duration of economic expansions and recession and many studies have used this approach to explore the price cycle for metals, crude oil, stock market, real estate, and others(Mark C. Roberts, 2009[8]; Paul, John, and Alasdair, 2001[9]; Linnea Polgreen, and Pedro Silos, 2009[10]; Roberto A. De Santis, 2003[11]; W. C. Labys, J.B. Lesourd, D. Badillo, 1998[12]; W.C. Labys, A.Achouch, M.Terraza,1999[13]). In reference to the price volatility of agricultural products, though Walter Bauernfeind and Ulrich Woitek (1996)[14] have observed cereal price cycles to have lengths of about 13, 8, and 3-5 years, only a few studies have examined the price volatility of agricultural products, let alone China's cereal prices in particular.

In light of concerns related to risk aversion and cereal price fluctuations, as well as the results of previous studies, we have a strong incentive to identify the cycles of China's cereal prices using the Bry-Boschan method and exploit the data on the average variation cycle for China's cereal prices as well as their influencing factors using survival analysis method.

The rest of our paper is organised as follows. The second section illustrates our use of the Bry-Boschan method and survival analysis. The third section presents the data source and its statistical characteristics. The fourth section analyses the empirical results. The final section presents conclusions and policy implications.

2. Methodology

In this study, as mentioned above, we first use Bry-Boschan algorithm to identify the phases of cereal price cycle in China. Then, we measure the mean duration of the cereal price cycle and the influence of the covariate variable for crude oil price on the fluctuation of price cycles using survival analysis. Here are the details of the Bry-Boschan algorithm and survival analysis.

2.1 Bry-Boschan algorithm

In this paper, the Bry-Boschan algorithm is used to identify price cycle duration, and the rules for selecting turning points are consistent with Bry and Boschan's (1971) business cycle dating algorithm. Based on the characteristics of China's cereal prices, the procedure and parameters used in this study are as follows:

1. Seasonal adjustments are applied to monthly cereal price data.
2. Extreme outliers are identified and replaced. The seasonal adjustment data are smoothed using a Spencer curve, and any points that are more than 3.5 times the standard deviation at the Spencer curve's average are replaced with the value that is 3.5 times of standard deviation at the Spencer curve's average, creating a new Spencer curve.
3. Troughs and peaks are identified. Once steps one and two have been taken for series (m_t), and after identifying its 3-month moving average and obtaining a new series (m'_t), troughs and peaks are identified as follows:

A. Peaks and troughs (TP_1) are selected in the smoothed series using the rules that a peak occurs at time t whenever $m'_t > m'_{t\pm k}$ and a trough occurs at time t whenever $m'_t < m'_{t\pm k}$ and when k=1 to 2.
B. The rule that peaks and troughs must alternate by selecting the highest of multiple peaks (or the lowest of multiple troughs) is enforced.
Then, the dates of the peaks and troughs become the first set of turning points (TP_1).

4. A second set of turning points (TP_2) is found using the Spencer curve.

A. The corresponding highest (or lowest) value is selected at a point within ±2 months of TP_1.
B. The minimum duration of 6 months is enforced by eliminating lower peaks and higher troughs of shorter cycles.
C. The rule that peaks and troughs must alternate by selecting the highest of multiple peaks (or the lowest of multiple troughs) is enforced.
5. A third set of turning points (TP_3) is identified based on the short-term moving average of two-month.
A. The corresponding highest (or lowest) value is selected at a point within ±2 months of TP_2.
B. The minimum duration of 6 months is enforced by eliminating the lower peaks and higher troughs of shorter cycles.
C. The rule that peaks and troughs must alternate is enforced. If there appear to be two or more consecutive peaks, the highest peak is selected and the lower peaks are deleted. If there appear to be two or more consecutive troughs, the rule works in the same way.
6. The final turning point (TP_4) is selected.
A. The highest (or lowest) value within ±2 months of TP_3 in the original series, or the TP_3, whichever is larger, based on the short-term moving average is identified.
B. Turns within 3 months of the beginning and end of series are eliminated.
C. Cycles whose duration is less than 6 months are eliminated.
D. Peaks (or troughs) at both ends of the series with lower (or high) values than those closer to the end are eliminated.

Using the above procedure will clearly indicate price cycle duration for cereals in China.

2.2 Survival analysis – Duration analysis

To increase understanding of the characteristics of cycle duration for cereal prices in China, survival analysis is used to measure the average time elapsed between two peaks (or troughs). This technique is also used to conduct an empirical analysis of the impact of covariate variables on the duration of the cycle phases. The following are the principals of survival analysis and its specifications.

If a continuous random variable T has probability density function f(t), which may be defined as the probability that a particular amount of time will elapse between one peak (or trough) to the next, the cumulative distribution function is as follows:

$$F(t) = \int_0^t f(s)\, ds = Prob(T \le t) \quad (1)$$

In the survival analysis literature (William H. Greene, 2007[15]), F(t) is known as the failure function so that the survival function is

$$S(t) = 1 - F(t) = Prob(T \ge t) \quad (2)$$

This function indicates the probability that the price cycle is greater than or equal to t. Given that the price cycle lasts until t, the probability that the price cycle will end in the next time interval Δt is as follows:

$$l(t, \Delta t) = Prob(t \le T \le t + \Delta t | T \ge t) \quad (3)$$

Thus, the hazard function is

$$h(t) = \lim_{\Delta t \to 0} \frac{Prob\ (t \le T \le t + \Delta t | T \ge t)}{\Delta t} = \lim_{\Delta t \to 0} \frac{F(t + \Delta t) - F(t)}{\Delta t S(t)} = \frac{f(t)}{S(t)} \quad (4)$$

It can be transformed as follows:

$$h(t) = \frac{-d\ln S(t)}{dt} \quad (5)$$

The integrated hazard function is therefore

$$\theta(t) = \int_0^t h(s)ds \quad (6)$$

Assuming that $S(t) = e^{-\theta(t)}$, the integrated hazard function is as follows:

$$\theta(t) = -\ln S(t) \quad (7)$$

In this paper, the hazard function determined according to the Weibull distribution, the Gompertz distribution and the exponential distribution, whose specifications are given in Table 1. There are two parameters for each distribution if there is no covariate variable: position parameter $\lambda=\exp(\beta_0)$ and scale parameter p. If p>1 in the Weibull distribution (or p>0 in the Gompertz distribution), the hazard rate to terminate a price cycle will increase; if p<1 in the Weibull distribution (p>0 in the Gompertz distribution), the hazard rate of ending a price cycle will decrease.

Table 1

Distribution	Hazard function h(t)	Survival function S(t)
Weibull	$h(t) = \lambda p t^{p-1}$	$S(t) = \exp(-\lambda t^p)$
Gompertz	$h(t) = \lambda \exp(pt)$	$S(t) = \exp(\frac{\lambda}{p}[1-\exp(pt)])$
Exponential	$h(t) = \lambda$	$S(t) = \exp(-\lambda t)$

Note: Weibull model in the following part is consistent to Weibull distribution, and Gompertz model in the following part is consistent to Gompertz distribution.

As mentioned above, there may be many other covariate variables that significantly affect cereal price fluctuations. If there is a remarkable impact of the crude oil price, it will be analyzed as a covariate variable, and its impact will be subsequently estimated and tested.

There are two types of survival analysis involving covariate variables. One is the accelerated failure time model. Though the specification of the model is the same as that in Table 1, the specification of λ is different as follows:

$$\lambda = \exp(\beta' x_i) \quad (8)$$

where x denotes a covariate variable that represents an indicator of crude oil price, which includes its mean, cycle-by-cycle rate of change and standard deviation.

The other type of analysis is Cox's proportional hazard model. The hazard function of Cox's proportional hazard model is defined as follows:

$$h(t_i) = \exp(\beta' x_i)\, h_0(t_i) \quad (9)$$

where h_0 is the "baseline" hazard rate, which is different for each object.

Then, the log-likelihood function of survival analysis can be written as

$$\ln L(\theta) = \sum \ln h(t|\theta) + \sum \omega_i \ln S(t|\theta) \quad (10)$$

where $\theta = (\lambda, p)$, and ω_i is a weighting variable: one weights the delayed entry observations using a type of inverse-probability weight to account for left truncation.

Thus, the parameters of the above models can be estimated using maximum likelihood estimation (MLE) with the help of the STATA software.

3. Data and the statistical description

The data for China's cereal prices that are used in this paper come from the China Price Information Network (www.chinaprice.gov.cn) and are converted from series of ten-day intervals into monthly series. The data for crude oil prices are UK Brent data and are obtained from IMF International Fund (www.imf.org).

Table 2 Statistical description of cereal prices and crude oil prices

yuan/kg; USD/barrel

	mixed wheat	soybean	late indica rice	maize	japonica rice	early indica rice	crude oil
max	1.90	5.19	1.97	1.68	2.16	1.95	133.90
min	0.99	0.75	0.73	0.87	1.21	0.99	9.80
mean	1.38	2.56	1.22	1.13	1.59	1.45	42.32
standard deviation	0.24	0.86	0.37	0.02	0.25	0.20	26.88
median	1.43	2.43	1.18	1.10	1.60	1.43	30.87
CV	0.17	0.33	0.30	0.02	0.16	0.13	0.64

Note: unit of cereal price is yuan/kg,unit of oil price is USD/barrel

Table 2 presents the statistics for the data from June 1997 to October 2009. According to Table 2, the mean maize price is the smallest at 1.13 yuan per kilogram, while that of soybeans is the biggest at 2.56 yuan per kilogram, and prices for the rest of the cereals range from 1.22 to 1.59 yuan per kilogram. The standard deviation of the soybean price is the biggest, which reveals that its amplitude of fluctuation is the largest. The price of maize has the smallest amplitude of fluctuation, with a range of 0.87-1.68 yuan per kilogram, the mean and standard deviation of which are 1.13 and 0.02 yuan per kilogram, respectively. The standard deviations of mixed wheat, late indica rice, japonica rice and early indica rice are 0.24, 0.37, 0.25 and 0.20 yuan per kilogram, respectively. Among the coefficients of variation (hereafter referring to CVs), which reflect the degree of dispersion, that of soybean price is the largest, followed by that of late indica rice and so on. For crude oil prices, the mean is 42.32 USD per barrel, and the standard deviation is as large as 26.88 USD per barrel, with fluctuation from 0.87 to 1.68 USD per barrel and a CV of 0.64.

4. Model Selection and Empirical Results

4.1 Model Selection

Table 3 Log-likelihood, AIC and SC values

	parameter models		
	exponential	gompertz	weibull
log-likelihood value	-80.309	-79.342	-73.288
AIC values	161.618	159.685	147.576
SC values	2.566	2.536	2.347

Note: AIC = -2(log-likelihood) +2(c+p+1), where c is the number of covariates except consistent and p is the number of ancillary parameters. SC=-2(log-likelihood/T) + k*log(T)/T where k is the number of parameters in the model and T is the number of samples.

To determine the best-fitting model from among the above survival models (the exponential model, the Weibull model and the Gompertz model), we calculate the evaluation indicators of log-likelihood value, AIC value and SC value. The decision rule is that the smallest value yields the best model. The results indicate that that the Weibull model is the fittest. Thus, the results attained using the Weibull model and Gompertz model are only provided as points of reference.

A statistical test is also undertaken to test or not whether Cox's proportional hazard (PH) assumption fits the data. The likelihood value is 21.20, and the significance level is 5%, indicating that the PH assumption can be accepted.

4.2 Empirical Results

4.2.1 Results identifying price cycles for China's cereal

Table 4 Characteristics of cereal price cycle duration

Cycles	mixed wheat	soybean	late indica rice	early indica rice	maize	japonica rice	crude oil
Expansion							
number	4	6	5	6	7	5	4
min duration	6	6	5	5	4	5	8
max duration	29	27	35	18	15	41	21
mean duration	15.0	13.8	18.4	9.5	7.6	12.2	17.3
standard deviation	9.8	9.1	13.6	4.9	3.8	16.1	6.2
Contraction							
number	3	7	6	7	8	5	5
min duration	1	2	2	1	3	4	3
max duration	10	10	6	18	18	29	22
mean duration	5.3	6.0	4.5	6.6	7.6	12.8	10.8
standard deviation	4.5	2.8	1.4	6.1	5.1	10.6	9.8
Overall cycle							
number	6	12	10	12	15	9	8
min duration	7	10	7	5	9	9	22
max duration	39	35	39	25	26	59	43
mean duration	21.2	19.7	21.5	14.8	14.9	24.0	29.4
standard deviation	13.0	9.5	12.1	7.5	4.8	18.1	8.0

Note: units of max duration, min duration and mean duration are months.

Table 4 shows not only the price cycles of six kinds of cereal specified by using the Bry-Boschan algorithm but also the duration of the crude oil price cycle, which is later used as the covariate variable in the survival analysis to explain the fluctuation in the cereal price cycle. There appears to be more contraction than expansion. Note that the mean duration of the cycles during expansion phases is longer than that in contraction phases except in the case of japonica rice. Late indica rice exhibits the most significant gap between mean cycle duration during the expansion phase (18.4 months) and that during the contraction phase (4.5 months); for japonica rice price, mean cycle duration during expansion phases is 12.2 months, which is 0.6 months shorter than in contraction phases. The mean duration for all cereals ranges from 12.8 months during periods of expansion to 7.1 months in periods of contraction. This suggests that cereal prices take less time to fall from the peaks to troughs than they do to rebound.

Of the six kinds of cereals, maize has the largest number of cycles overall, with 15 overall cycles. Soybean and early indica rice follow with 12 overall cycles each. The mean cycle duration for early indica rice is the shortest, with a length of 14.8 months, while that of japonica rice is the longest, with a length of 24 months. Additionally, the standard deviations of the overall price cycles of cereals range from 4.8 months for maize to 18.1 months for japonica rice, which indicates that there are significant differences in the amplitude of fluctuation among different cereals. Thus, we observed that cereals used for direct consumption exhibit relatively long price cycles compared to those for livestock feed and biofuel materials.

4.2.2 Empirical results of Survival analysis

Table 5 Results of the survival analysis

covariate variables		weibull		gompertz		cox	
-	haz.ratio	0.449	**	0.017			
		(0.106)		(0.012)			
	mean	20.558					
	median	18.112		16.939			
mean of oil price	covariate variables	0.992		0.994		0.994	
		(0.007)		(0.007)		(0.007)	
	1/ln(p)	0.467	***	0.019			
		(0.107)		(0.012)			
	p	1.595		52.632			
variance ratio of crude oil price	covariate variables	0.331	***	0.362	***	0.375	***
		(0.078)		(0.089)		(0.097)	
	1/ln(p)	0.620	***	0.039	***		
		(0.103)		(0.013)			
	p	1.859		25.641			
standard deviation of crude oil price	covariate variables	0.812	***	0.831	***	0.866	***
		(0.035)		(0.038)		(0.034)	
	1/ln(p)	0.795	***	0.060	***		
		(0.111)		(0.016)			
	p	2.214		16.7166			

Note: The figures in the table are hazard ratio, and the figures in the brackets are the standard deviation of the hazard ratio, only a few of figures are mean value or median.*,**and*** separately denote that hazard ratio is significant at the level of 10%, 5% and 1%. 1/ln(p)'s hazard ratio is given in Weibull model ,while (1/p)'s hazard ratio is given in Gompertz model.

The results shown in Table 5 are achieved using the survival analysis model based on the cereal price cycles. According to Table 5, the parameter estimation results achieved without a covariate variable using the Weibull model are significant at the level of 5%; however, those achieved using the Gompertz model are not significant at that level. The mean price cycle duration for cereal is 20.56 months under the Weibull model. Furthermore, none of the parameter estimation results achieved using the mean crude oil price as a covariate variable during the survival analysis are significant at the level of 5%. This also provides evidence that there is no impact of mean crude oil prices on the cyclical variation in cereal prices.

When we respectively use the variance ratio or the standard deviation of crude oil prices as a covariate variable in the Weibull model, the Gompertz model and Cox's proportional hazard model, the parameters of the covariate variable are significant at the 5% level, which reveals that the cycle-on-cycle variance ratio or the standard deviation of the price of crude oil has an impact on the cyclical variation in cereal prices. Thus, we conclude that the variance ratio and the standard deviation for crude oil prices are the important factors affecting the price cycles for China's cereal.

Table 6 Covariate variable elasticity of cereal price cycles

covariate variables		weibull	cox
variance ratio of oil price	mean	-0.486	-0.438
	std.dev.	0.642	0.578
standard deviation of oil price	mean	-1.578	-1.095
	std.dev.	1.349	0.936

Table 6 shows the covariate variable elasticity of the hazard rate for cereal price cycles calculated using the results estimated via survival analysis. According to the covariate variable elasticities of cereal price cycles in Table 6, when the rate of change for crude oil prices is a covariate variable, the elasticities of the hazard rate for cereal price cycle calculated using the results from the Weibull model and the Cox proportional hazard model are -0.486 and -0.438, respectively. This indicates that if there is a 10% increase in the change rate for crude oil prices, the decrease in the hazard rate for cereal price cycles will rise by 4.38%-4.86%. In addition, when the standard deviation for crude oil prices is a covariate variable, the elasticity of the hazard rate for cereal price cycles calculated using the results of the Weibull model and the Cox proportional hazard model are -1.578 and -1.095, respectively. This reveals that if the standard deviation for crude oil prices rises by 10%, the decline in the hazard rate for cereal price cycles will increase by 10.95%-15.78%.

5. Conclusion

Examining cereal price cycle using the Bry-Boschan algorithm, this paper uses survival analysis to measure the mean duration of China's cereal price cycle and demonstrates the effect of international crude oil price on the price cycle for cereal in China. The resulting conclusions and policy implications are as follows.

First, based on the Bry-Boschan algorithm, there appear to be significant differences in the price cycles of the different Chinese cereals. The price cycles for japonica rice, late indica rice, mixed wheat and soybeans are relatively longer, while those of early indica rice and maize are shorter. The mean duration of the price cycles is between 14.8 and 24 months, which is far shorter than the mean duration of price cycle estimated using traditional statistical indicators (Hui Cao, 2007; Bauernfeind, Ulrich Woitek 1996). The cycles for cereal prices in China are relatively short, which indicates that China's cereal prices are characterised by changeability and vulnerability. Therefore, China's policy-makers should fully consider the features of China cereal market, especially the average length of the price cycle for different cereal types, given that the types of cereal used for direct consumption have relatively long price cycles compared with those used for livestock feed and biofuel materials. After determining a corresponding agriculture or cereal price policy, it will be important to accelerate the pace of policy adjustment according to the actual situation, taking into considerations such as phase of the cereal price cycle, to avoid the potential negative effects of long-term policy implementation.

Secondly, the results obtained using survival analysis indicate that the variation ratio or standard deviation of the international crude oil price has a notable influence on China's cereal price cycles. In particular, the mean elasticity (absolute value) of the hazard rate for China's cereal price cycles to the standard deviation of crude oil prices is greater than 1, which illustrates that the effect of the standard deviation of crude oil prices on the hazard rate for China's cereal price cycles is extremely significant. If the aim is to avoid price risks, when we build the warning system for China's cereal prices, it will be necessary to monitor the variation in international oil prices and evaluate its impacts on China's cereal prices.

Finally, our paper only studied the effect of crude oil prices on the hazard rate for China's cereal price cycles. However, other co-variables, such as the auction time for the cereal market, transaction volume, weather conditions, and so on, are also likely to produce affects on the hazard rate for China's cereal price cycles. This is a drawback of our study and an area where research should be further intensified in the future.

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