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Identification of Types and Driving Forces for China's Hog Price Cycle Based on the Hilbert–Huang Transform

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This paper applied Hilbert–Huang transform to analyze the decomposition of China's hog price cycle from 1994 to 2013. Decomposition results indicated the existence of cycles having one trend and four main modes, including an economy with a 4–month cycle, an 8– to 9–month cycle, a 17– to 19–month cycle, and a 42– to 43–month cycle. High similarity was noted between the hog price cycle of 1994–2013 and 1910–1969 in the United States. The hog price cycle was exceptionally determined by the biological nature of pig breeding. Results also suggested that the price control of hogs should respect the law of price cycle rather than arbitrary intervention.

Key words: Hilbert–Huang transform, Hog price cycle, Nature of price fluctuation

INTRODUCTION

China is the largest hog consumer worldwide. It has promoted a great number of related industries, such as pig farming, genetic improvement, veterinary drug, slaughtering and meat processing. Hog production and hog–breeding industries occupy important places in the national economy and are of great strategic significance. As the saying goes, "hog and grain maintain social stability". However, the hog industry has been confronted with the rise and fall in multiyear cycles as the industry expands and contracts since the government relaxed control on the purchasing and selling price of hog and pork in 1985. Considerable attention has focused on the fluctuation in hog prices in a cyclical manner. The inflation data in Fig. 1 show that food inflation, which manifests in the inflation of meat products or meat price, primarily embodies the inflation of China's economy. Pork accounts for more than half of the China's meat consumption, and the price of mutton and beef presents a stable upward trend. Consequently, fluctuations in hog production and prices have aroused public concern. Thus, exploring the price cycle of hog to predict the consumer price index (CPI) and the understanding of macroeconomic situations in China are of useful significance.

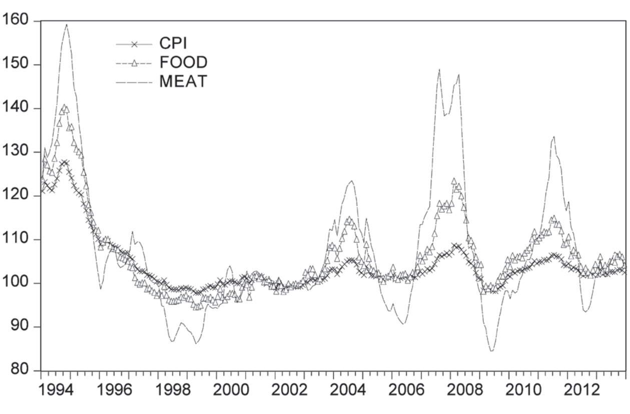

Fig. 1. The meat price and inflation in China.
Resources: NBS

Research on the price cycle of hog first appeared in the 1930s. Coase and Fowler discussed the hog market in the United Kingdom in 1937. Ezekiel (1938) synthesized other literature at that time, proposed a cobweb model, and summarized the basic characteristics of the hog market, which concluded that the inelasticity of short–term supply and the elasticity of long–term supply induced the periodic fluctuations in hog prices. Since the 1930s and for more than 20 years, hog price cycle had been an important research field in agricultural economy. Harlow (1960) studied producers' reaction to the price when making decisions and estimated that the hog price cycle was roughly four years. This estimation was in line with the study of Coase and Fowler (1937) but different from Ezekiel's (1938) two–year expectation. The problem of reacting to the conflict between increasing piglet and hog in the price cycle remained unsettled. The principles of traditional cobweb model explain that hog production cycle is two years owing to the one–year time lag between supply and price. By contrast, the hog cycle is four years based on the cobweb model with two–year lag and the Harlow model. Moreover, Hayes and Schmitz (1987) argued that the producers who gained the knowledge of hog cycle and changed rules could make their production decisions based on a counter cycle, which would eventually reduce and eliminate the hog cycle. Hayes and Schmitz explained that the producers neglected relevant information and the availability of an efficient market. The development in the theory of business cycle suggests that the features underlying the hog cycle cannot be captured by linear models alone. At the same time, there are many different types of regime switching models, capable of depicting asymmetric

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behavior, which is the important reason for renewed interest in hog cycle research. More research results supported nonlinearities in the hog–corn cycle (Chavas and Holt, 1991; Holt and Craig, 2006). Finally, hog cycle was not static, and certain unexpected external shocks (i.e., feeding techniques, natural disasters, and diseases) might further complicate the cycle.

Literature on hog cycle in mainland is relatively deficient compared with that in Taiwan. This deficiency is chiefly attributed to the serious distortion of husbandry statistical data (Zhong, 1997; Lu, 1999; Jiang *et al.*, 2003); at the same time, accurate hog output and consumption were inaccessible. The earliest data of hog stock level only date back to 1994; numbers of sows with fertility cannot be obtained in reports until 2007 and were inaccurate. Given the lack of breeding and slaughter data, the same method for accurately estimating the hog production cycle cannot be applied. Zhao (2009) revealed that the cyclical fluctuation in hog production was primarily six years in China. Zhao used the spectral analysis method and cross–spectrum technology; however, hog production cycle was unstable based on spectrum density. The monthly published national price trends for hog products and fodder, including piglets, growing and fattening hogs, hog and corn, are commonly considered to be accurate. The majority of the existing studies focus on hog price cycle from the perspective of price and attempt to reveal the internal fluctuation pattern of hog prices.

Mao and Zeng (2008) studied the hog market price cycle using the monthly price data of 1995–2008 with Hodrick–Prescott Filter. They observed a significant periodic fluctuation of approximately 35 to 45 months in hog market price, which differs from the characteristics of piglet price volatility. Wu *et al.* (2011) reported that hog price in China mainly consisted of a long–term trend mode, a 17–month–scale economic cycle mode, a 51–month–scale breeding cycle mode, and a short–term auto modulation cycle mode. However, the sample interval (January 2000 to May 2009) was relatively short while taking into account policy intervention. The effects could not be depicted in details with the presence of policy intervention. Some points of the description of the hog breeding cycle in the research are open to discussion.

The aforementioned studies are highly significant for understanding the hog price cycle, and they narrow down the cause analysis of hog price fluctuation into hog production cycle and epidemic disease. However, two crucial issues need to be further explored: whether the hog price cycle contains different time scales and whether external shocks (i.e., epidemic and policy intervention) influence pig price cycle. Thus, the article attempts to decompose the information on hog price fluctuation on different scales using Hilbert–Huang transform. Compared with the traditional statistical method, Hilbert–Huang transform performs well in piecewise linearization and the stabilization processing of non–linear and non–stationary data. Furthermore, Hilbert–Huang transform can effectively extract implicit multi–time scales and trends from time series. The rest of this paper is organized as follows. Section 2 introduces the research methods and data. Section 3 investigates hog price cycles on different scales using the Hilbert–Huang transform method; discusses the hog price cycle in the United States before 1970; and provides explanation based on the biological properties of hog breeding. Finally, section 4 concludes the paper.

METHODOLOGY

Hilbert–Huang Transform

The Hilbert–Huang transform (HHT) method was proposed by Chinese–American Huang and his partners in the academy of engineering in 1998. HHT analyzes the non–linear and non–stationary data. HHT is a unique spectrum analysis method that consists of two processes, namely, empirical mode decomposition (EMD) and Hilbert transform. EMD decomposes complex data sets into limited numbers of intrinsic mode functions (IMFs). IMF effectively depicts every local oscillation structure of the original data; the Hilbert spectrum based on IMF exhibits good time–frequency locality. EMD method is a group of dynamic filter clusters, and the "base" utilized in the decomposition is self–adaptive according to the original signal, identifies the inherent oscillation mode through the characteristic of time scales, and conducts EMD decomposition. Thus, any complex data signal can be expressed as a sum of a finite number of IMFs. The decomposition process is as follows:

(1) All of the local maximum values and minimum values are found in the original time series $x(t)$. The local maximum and minimum values are assigned as the upper and lower envelope lines, respectively, using a cubic spline. The mean value of the upper and lower envelope curves is the average envelope noted as m_1. The difference between time series $x(t)$ and m_1 is calculated as h_1: $x(t) - m_1 = h_1$. If h_1 does not meet the two conditions of IMF, the above process is repeated and the following formula is obtained: $h_1 - m_{11} = h_{11}$, where m_{11} is the mean value of the upper and lower envelope of h_1. This process is repeated until it can perform as a function of IMF: $h_{1(k-1)} - m_{1k} = h_{1k}$. The definition is the first IMF isolated from the original time series, which includes the local minimum scale.

(2) c_1 is separated from the data $x(t) - c_1 = r_1$. Given that r_1 generally contains the component of IMF, r_1 should be processed as new data until r_n basically shows a monotonous trend or a very small measurement error. $r_1 - c_2 = r_2, \ldots, r_{n-1} - c_n = r_n$. Therefore, $x(t) = \sum_{i=1}^{n} c_i(t) + r_n$. n modes and trend r_n are obtained.

The decomposition process can be summarized as the following specific decomposition algorithm:

Let $x(t)$ represent the discrete time sequence need to be processed.

Step 1 Initialization: Let $r_0(t) = x(t)$, $i = 1$ (index target of IMF).

Step 2 Extract the ith IMF.

(a) Initialization: $h_0(t) = r_{i-1}(t), j = 1$.

(b) Find the local maximum value and local minimum value of $h_{j-1}(t)$.

(c) Taking the local maximum value as the node, use cubic spline interpolation to form the upper envelope line of $h_{j-1}(t)$: $u_{j-1}(t)$; similarly, form the lower envelope line $l_{j-1}(t)$.

(d) Find the mean value of the upper and the lower envelopes, $m_{j-1}(t) = \dfrac{u_{j-1}(t)+l_{j-1}(t)}{2}$.

(e) Let $h_j(t) = h_{j-1}(t) - m_{j-1}(t)$.

(f) If the difference between the times of $h_j(t)$ crossing zero and the number of extreme value point is 1 to the top, and $SD_j = \sum_{k=-\infty}^{\infty} \dfrac{|h_{j-1}(k)-h_j(k)|^2}{h_{j-1}(k)^2}$ is less than a given constant, $imf_i(t)=h_j(t)$; otherwise, skip to (b) and let $j = j+1$.

Step 3 $r_i(t) = r_{i-1}(t) - imf_i(t)$.

Step 4 If $r_i(t)$ at least contains two extreme value points, skip to Step 2 and let $i = i+1$; otherwise, complete the decomposition, and let $r_i(t)$ be the margin reflecting trend variation.

Three advantages of HHT can be seen through the above algorithm compared with traditional time series decomposition methods: (1) No problem is found on specific model setting; (2) the parameters of the algorithm are intuitive and simple; and (3) the calculations are convenient, and the results exhibit good robustness.

Data Source

National animal husbandry station and China feed industry association have collected and reported the statistics of 450 animal products and fodder price information points of China, including 228 samples of market prices of animal products and fodder from June 1994 to May 2013 (see Figure 2).

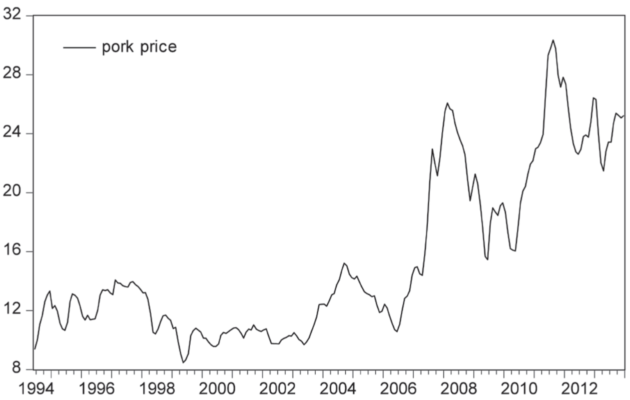

Fig. 2. The pork price.
Resources: CAAA(http://www.caaa.cn/)

RESULTS

Existence of Hog Price Cycle Types

According to the analysis of Ezekiel, cobweb theory cannot be applied to all of the products unless three conditions are satisfied. (1) Production decisions in a perfect competition market are completely determined by the producer, who reacts to the price that is assumed to remain unchanged in the short term. The production plan will not affect the market. (2) The production plan will cost at least one full period to change the production. (3) The price is determined by the current supply situation, that is, the current supply determines the current price.

For the live hog market in mainland China, the government has waived its hog price intervention since 1985. Hog price was chiefly determined by the market after the rationing system ended sometime in 1990. Moreover, the hog–breeding method in mainland China is relatively conventional and lags behind. The subjects are primarily small–scale retail investors and specialized households that adjust the production mainly according to their price expectation. Such an adjustment induces a relatively regular periodic fluctuation in hog prices. Figure 3 shows that approximately five cycles of China's hog prices occurred from 1994 to 2013. The first two cycles were more stable without considerable price volatility, and the subsequent three cycles demonstrated significant price volatility. Each cycle lasted an average of roughly 48 months. Figure 4 shows that the coefficient of autocorrelation regression with 60 lags, which also indicated that the hog price is obviously cyclical and rough. The hog price cycle was approximately 40 months.

Most related studies support the idea that hog price in China is featured by nonlinear adjustment (Mao and Zeng, 2008; Hu and Wang, 2010). The research conclusion of Hu and Wang (2010) shows that a significant threshold effect exists on the linear adjustment of hog

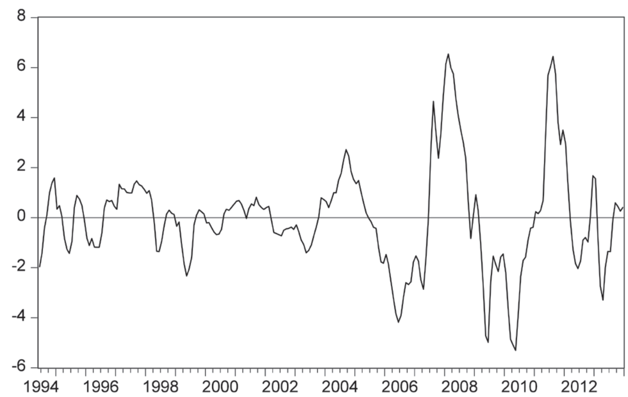

Fig. 3. The detrended hog price (after Hodrick–Prescott Filter).

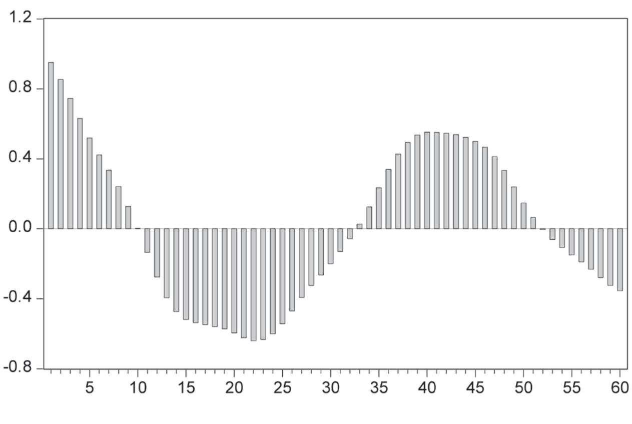

Fig. 4. The modes of autocorrelation in hog price with 60 lags.

price, and the one–period–lagged threshold value is 124.4, which divides the hog price index into two portions. The hog price index is more stable and with a smaller fluctuation when the hog price index is in the lower portion. When the hog price index is in the upper portion, its fluctuation rapidly increases, which affects both producer and consumer and endangers the stable and healthy development of the hog industry. This situation clearly demonstrates the existence of at least two different types of hog price cycles.

Breeding Cycle of Hogs

Procedures of modern hog breeding include breeding for sows, conceiving, farrowing, suckling, weaning, and finishing. Farmers will increase the supply accordingly if the short supply of hog occurs or is likely to occur. Farmers then have to make five choices, namely, to arrange hogs for slaughter ahead of time, accelerate the growth rate of hogs, add piglets in feeding, improve the conception rate, or supplement the gilt. These situations are presented Table 1. Therefore, different decisions induce diverse amounts of hog supply, which naturally spur disparate pricing mechanisms.

The supply source of slaughtered pigs is sow. The number of sows decides the supply capacity of pig farmers nine months later. Hence, the quantity change in sows is the root cause of hog price cycles and hog price fluctuations. (Bai, 1988; Wang and Xiao, 2012). Under the condition that the number of sows is relatively stable, the typical evolution path of hog cycle is as follows: rebound of hog prices → increase in piglet price → supply of additional gilts → increase in hogs and decrease in hog price → no supplement of gilts → decrease in hog supply and increase in price. Farmers will cull and slaughter the sow based on economic consideration if the hog price continues to fall in the long run. However, farmers will begin to add pigs into feeding when the hog price bottoms out. Four–month old productive sows are introduced and fed for another four months to farrowing. The sows could develop after a long period. Sow conception takes about 114 days, and farrowing and finishing take another 160 days. Given that the price continues to plunge would spur the slaughter of sows and create the situation of "hog price falling—farmers negative on adding new pigs—piglets price goes down—unselected sows to be slaughtered" in the hog market, providing insurance for sows is deemed to be beneficial to stabilize the number of the productive sows in feed. Providing insurance can avoid entering into long periods of sow–slaughter caused by hog price fluctuations. Farmers who face different market prices make varied choices accordingly. These choices significantly impinge on hog supply, and then hog price would present diverse price cycles considering that hog consumption is stable and seasonal.

Analysis of Hilbert–Huang transform results

Applying Hilbert transform on a singular value of IMF decomposed from hog price using the EMD method, we obtain the time–amplitude and time–frequency spectrum of each IMF singular value. The result indicates that China's hog price cycle contains four concrete IMF states of different cycles and a long–term trend, which reflects the hog price variation's complexity with multi–time and multi–level features.

From the perspective of tendency figures, the nominal price of China's hogs went through a temporary falling process. The hog price remained relatively stable from 1999 to 2002. The stability might be attributed to the deflation of China during this period. However, the nominal price of pigs presents an obvious rising trend from 2003 (see Table 2). The cycle of China's hog price includes four singular values of IMF, namely, 4 months, 8 to 9 months, 17 to 19 months, and 42 to 43 months.

Table 2. Cycle of different IMF singular values in hog prices

	IMF1	IMF2	IMF3	IMF4
China	4.4700	9.1862	19.7812	43.3086
USA	3.9384	8.7404	17.3945	42.2911

Little information is available about the exact source of different cycles. This paper attempts to identify the decision–response relationships within the hog industry. First, IMF1 presents a quasi–4–month periodic oscillation. Wu (2011) asserts that IMF1 singular value is a short self–regulated cycle of hog price. However, the present study argues that the four–month period comes significantly closer to the farmer's reflection of the market hog price. To chase the competitive price, farmers tend to accelerate the growth rate of hogs for slaughter when the price increases. Farmers can also make the same decision when the price remains relatively low in the market. Hog price tends to decrease when the supply of hog increases, and farmers are inclined to reduce the number of hogs for slaughter under a condition that lacks an external influence. Hence, the price naturally increases and enters into a new cycle.

Table 1. Decision–making Mechanisms and Breeding Period of Pig Farmers

Decision of Farmers	Period/Month
Slaughter pigs ahead of time or accelerate the growth of pigs	Relatively short period
Add piglets in feeding	4–5
Pregnancy–parturition–fattening	9
Parents' generation pig–backup and sow–sow–pregnancy–parturition–fattening	18

Resources: Based on field investigation and relevant paper

The short run cycle depicts a situation in which the hog producers attempt to make free decisions with the capacity utilization of building and equipment subject to biological and technical constraints.

Second, IMF2 is high–frequency oscillation; its amplitude and frequency uniformly vary within an entire period. The nine–month cycle is near the process of conception–farrow–feeder (see Table 1), in which hog producers have freedom to manage inventory control.

The short run cycles of 6, 4, and 3 months may be explained by seasonal, weather, and market signals coupled with capacity utilization of building and equipment subject to biological and technical constraints. Interactions with inventory control management affect short cycles more than they affect long cycles.

Additionally, the cycle is approximately 42–43 months from the perspective of IMF4. This result is consistent with those obtained by Mao and Zeng (2008), who employed Hodrick–Prescott filter algorithm to show the significant fluctuation in market hog prices. The results are highly similar to the four–year cycle and the Cobweb continuous motion. Talpaz (1974) noted the effects of the national business cycle and other outside forces operating in the long run. The cycle depicts the long hog cycle even on the condition of slaughtering sows. The sample interval showed that the decrease in sow supply occurred in the first half year of 2003 and 2006. Without cases of sow slaughtering, the hog prices will present a long period of roughly 19 months, as depicted by IMF3. However, Talpaz (1974) explained that the producers' evaluation of profit prospects based on the relationship between the corn supply of the current year and that of the previous year was responsible for the 16–month cycle. Thus, the large–scale slaughtering of sows is key to the switch between IMF3 and IMF4.

The price will change future decisions and production processes in the hog industry if the market signal is effective. The hog producer builds or remodels facilities and invests in a larger breeding herd during periods of expansion. Hog producers have many choices even during the expansion. The investments have different time spans in their consequences. The producer during periods of contraction continues to bear the consequences of the long–term investment made during expansion. Thus, the combination of different cycles is imaginable because of numerous simultaneous decision–response relationships, which induce equilibrium and disequilibrium positions.

This paper also investigated the U.S. hog price cycle when it was at a stage where its development level was similar to China's current level. It took into account the modernization and scaled production of hog breeding in the United States after the 1980s and the stable fluctuation in hog prices. A total of 720 samples of U.S. hog price material from January 1910 to December 1969 from the U.S. National Agricultural Statistics Service were obtained. Based on the price data before 1970, the U.S. nominal hog price between 1910 and 1946 remained relatively low and later showed a stable rising trend. The hog price cycle between the United States and China shows a relatively high similarity. The hog prices in both countries exhibit a significant resemblance in the IMF singular value in the sample interval (see Table 2), namely, 4 months, 8 to 9 months, 17 to 19 months, and 42 to 43 months. The hog price cycle between China and the United States shows a considerable similarity. However, their price fluctuations widely differ. The IMF4 of the United States has a larger fluctuation amplitude than that of China. The results significantly differ from those obtained by Talpaz (1974). Talpaz argued that

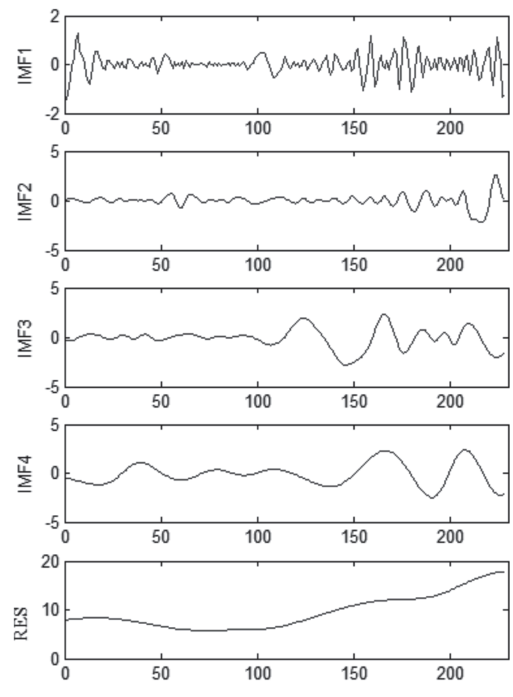

Fig. 5. The decomposition results of hog price in China.

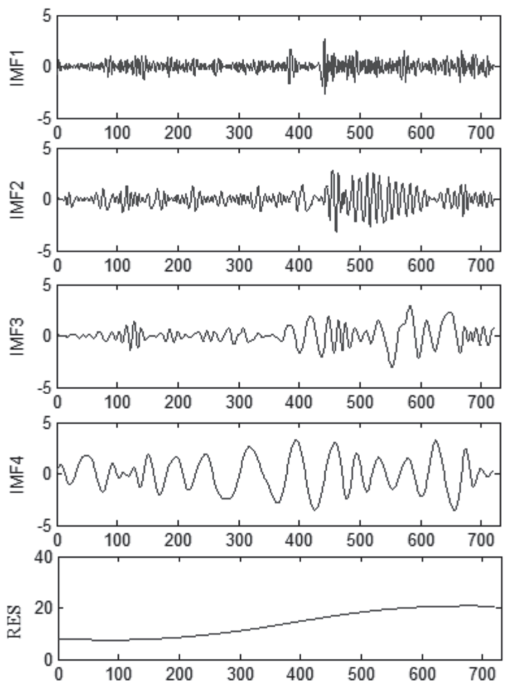

Fig. 6. The decomposition results of hog price in USA.

hog prices followed several different cycles, each of which exhibited a different period and magnitude. However, explaining the long run cycles (i.e., 48–month, 32–month, and 16–month cycles) and the short run cycles (i.e., 6, 4, and 3 months) is difficult.

This study has similarities with Talpaz (1974). Both studies adopted a long price cycle, a relatively long price cycle, and a relatively short price cycle. However, Talpaz's research did not provide a reasonable explanation for the result. By contrast, this paper contended that no significant difference existed between a 3–month cycle and a 4–month cycle; theoretically, such a subtle difference would not appear in two distinct cycles.

The formation of the U.S. hog price in 1970 and that of China's hog price in 1994 to 2013 are independent. China's international hog transaction accounts for a small proportion, and the intervening policies considerably differ between the U.S. and Chinese markets. The key cyclical properties for both countries are nearly identical despite the wide differences in scale, technologies, management, and policy intervention. The results suggest that the price cycle depicted by four different IMF singular values is primarily attributed to the biological nature of pigs.

Finally, whether the epidemic disease will alter the price cycle remains to be solved. Exploring the switch between different cycles caused by the outside shock is necessary. Liang *et al.* (2011) classified the emergencies that influence hog market into the following categories: (1) only affect supply, not demand and circulation; (2) only affect circulation and demand, not supply; (3) only affect circulation, not supply and demand; (4) only affect supply and circulation, not demand; and (5) only affect demand, not supply and circulation. Changing the supply or demand during the spread of an epidemic disease merely alters the hog price ratio between its supply elasticity and demand elasticity. The hog price cycle will naturally be determined when the duration of lag is fixed. However, factors that affect supply may switch the price formation in different periods; therefore, the spread of the disease would possibly change the hog price cycle and trigger the switch from short period to long period because of the sharp decrease in sow supply and the incapacity to add pigs for slaughter owing to the low survival ratio of piglets. Some examples include the blue–ear pig disease in 2001 to 2002 and the swine disease in the northern area in 2009. Epidemic diseases seriously affect the supply of productive sows and piglets. Therefore, the long period dominates hog prices in the market and the increase in price volatility. Strengthening the prevention of epidemic diseases is conducive to the healthy development of the pig industry. The acceptance of the above analyses and the simultaneous operation of four different cycles in an attempt to reach market equilibrium help improve the hog industry's performance, avoid the appearance of long period cycles, and leave the short period cycles unaffected.

DISCUSSION

Hilbert–Huang transform is a price signal analytical method that is applicable to nonlinear and non–stationary series. This study applied HHT to analyze hog prices and extract the change in real price signals. The results indicate that the variation in hog prices consists of four typical IMF singular values of different scales, namely, 4 months, 8 to 9 months, 17 to 19 months, and 42 to 43 months. Overall, the hog price cycles of 1994 to 2013 in China and 1910 to 1969 in the United States are highly similar, and the hog price cycle is exceptionally determined by the breeding cycle, which is consistent with the biological nature of pig breeding.

Therefore, this study asserts that the fluctuation in hog prices should be perceived from a scientific and rational perspective. Both the hog prices in early United States and the current periodic fluctuation in hog prices in China demonstrate regular movements of the hog market under the condition of the market economy. The principles of microeconomics emphasize that the lagging property of the hog industry is the core factor in periodic fluctuation. The principle of the market should be followed, and direct intervention should be avoided during hog market intervention. First, productive sows constitute the foundation of the development of hog breeding, and maintaining a reasonable scale is the premise for its stable development. As long as the stable supply of productive sows and high survival rate in livestock breeding are guaranteed, the amplitude and long period fluctuation in prices will not appear owing to the relatively low breeding cycle in the current breeding technique. Therefore, improving the insurance policy of productive sows and avoiding their large–scale slaughtering are imperative. Second, building a benign system of stock breeding, disease control, and technology promotion prevents the large variation in hog prices caused by epidemic diseases. Finally, strengthening the construction of information service and early warning mechanism can assist the government in grasping the dynamic data of productive sows, gilts, and piglets in real time, and thereby guide farmers to arrange production rationally and scientifically.

The data of this study have already covered the hog price monthly material of China for 20 years. However, this study is unable to capture the variations in hog price cycles compared with those in a longer cycle. Moreover, this paper does not provide abundant evidence for the price cycle of 4–month and 9–month cycles. Finally, this paper focuses on the hog cycle of China and its comparison with that of the United States. The understanding of the dynamics of hog price can be improved by collecting additional hog price cycle information and comparing different dimensions among many developed countries.

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