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RESEARCH ARTICLE

Construction and application of milk-feed price ratio model-based on data from large scale dairy farms in China

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ABSTRACT

Despite rapid development, the Chinese dairy industry still faces problems such as the lack of pricing power for dairy farmers, high fluctuations in raw milk and feed prices, imbalances between supply and demand, and low farming motivation. As an indicator with important geographical characteristics, the milk-feed price ratio (MF) is a critical reference indicator for setting raw milk prices and measuring farm profitability. The main aim of this study is to construct an appropriate milk-feed ratio model for China using statistical data for 2018-2020, which provides references for other developing countries. A vector error correction model was used to illustrate the long-term covariance between raw milk prices and feed prices in China and to analyze the feed structure of large-scale Chinese farms. The study found that the price weights of corn, soybean meal, corn silage, and alfalfa were 27%, 17%, 30%, and 26%, respectively, which are significantly different from those of developed countries, and the parameters of the model for the MF in different production areas in China also varied significantly. The milk-feed ratio in China has remained above 1.89 in the last three years. Seasonal variations in raw milk prices lead to a U-shaped trend in the MF. In recent years the MF in China has changed from a low level to a medium level, showing an upward trend, with large-scale farms at a profitable level.

Keywords: Application of MF; Granger causality test; MF model; Large scale farm

INTRODUCTION

The dairy market in China has steadily and substantially improved after the Chinese government took drastic measures in the wake of the "Melamine" incident in 2008. In 2020, China's dairy cows increased by 72.9% compared to 2008, with raw milk output 34.401 million tons, accounting for 4.1% of total global output, The proportion of dairy farms with more than 100 heads in stock reached 67.2%[1], and 95% of large scaled dairy farms were equipped with TMR (Total Mixed Ration) mixers, an increase of 47.7 percentage points over 2008[2]. The proportion of integrated milk sources of dairy enterprises has also been expanding. However, at the same time, China faces a series of problems, such as the lack of pricing power of dairy farmers, and significant fluctuations in raw milk and feed prices. The oligopoly market of China's dairy industry and the "vertical integration with dairy enterprises as the core" model have strengthened the market power of dairy enterprises but weakened the pricing power of dairy farmers. Remarkably, the rise of Sino-US trade frictions and trade protectionism in 2018 has gradually revealed the disadvantages of China's higher dependence on unilateral feed trade, which resulted in a significant fluctuation in Chinese feed prices. In 2021, the average prices of corn and soybean were 2,820 and 3,790 RMB/ton, respectively, an increase of 35% and 17% from 2019[3]. However, there is no corresponding mechanism to change the price of raw milk, thus seriously affecting production incentives

1 Data sourced from the World Food and Agriculture Statistics Yearbook 2021 (http://wtpf.secpc.org.cn/upload/images/2021/11/23c1eee48498228f.pdf), National Bureau of Statistics of China (http://www.stats.gov.cn/tjsj/ zxfb/202102/t20210227_1814154.html).

2 Data sourced from "Situation analysis of the development of full mechanisation of dairy farming in 2022"

3 Data source from the Ministry of Agriculture and Rural Affairs of China Agricultural Price Monitoring(http://zdscxx.moa.gov.cn:8080/nyb/pc/index.jsp).

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and the sustainable and healthy development of the dairy industry. Therefore, it is crucial to enhance dairy farmers' ability to cope with market risks and improve their voice in the market by exploring the relationship between raw milk prices and feed prices and establishing an effective raw milk pricing mechanism.

The milk-to-feed price ratio (MF) is an effective basis for the price setting of raw milk and an important indicator to measure the profitability of dairy farming (Neyhard et al., 2013; Tian et al., 2015; Bailey, 2008). It has been widely applied in developed countries due to the standardized dairy production and professional pricing system (Yuan and Wang, 2017). The United States Department of Agriculture has regularly announced the MF since 1985(Baum et al.,1954; National Agricultural Statistics Service,2010). The price changes of milk and feed are adjusted in time to guarantee the income of dairy farmers (Wang, 2008; John and Conrad,1959). The smaller the MF, the lower the farming income and the lower the farming enthusiasm (Horne, 2020). Other livestock and poultry also use a similar ratio to measure breeders' incom. The price ratio of pork to corn is used to measure the income of pig breeding (Blosser, 1965; Meilke, 1977), and the price ratio of broiler to corn is used to measure the income of poultry breeders. (Goodwin et al., 2007). With the increase in scale and standardization of livestock and poultry breeding in China and other developing countries, representative indicators of breeders income such as the pig-to-food ratio and egg-to-feed ratio have also begun to be used to guide production (Hong, 2012; Liu, 2014; Zhou and Hou, 2017; Yuan and Wang, 2017). The Chinese Ministry of Agriculture and Rural Affairs also regularly publishes the pig-to-food ratio and egg-to-feed ratio for the whole country and major provinces, In contrast, the measurement of milk-feed ratios has not been widely used. Therefore, there is a need to study the construction of a suitable MF model for China.

Countries with developed dairy industry have valuable experience in the calculation of MF. Wolf (2010) and Bailey (2008) analyzed the relationship between MF and income over feed costs (IOFC), They explained in detail that the MF is calculated from raw milk prices and feed prices, where the feed prices are calculated from soybeans, corn, and alfalfa. The National Agricultural Statistics Service(2009) stipulated the MF calculation: the price weights of soybeans, corn, and alfalfa are 8%, 51%, and 41%, respectively. Combined with the application experience of milk ratios in developed countries in the dairy industry, the key to constructing milk ratio models lies in selecting representative feeds and determining feed price weights. Studies of milk feed ratios in China have argued that feed prices are equal to the sum of the weights of maize and soybean prices (Guo, 2010; Xian et al., 2015). In addition to maize and soybean, maize silage and alfalfa grass are already essential feed inputs for dairy farming in China (Zhang, 2019). Hence, using corn and soybean only to measure MF is not representative, At the same time, there are regional differences in feed weights in the MF model due to differences in farming habits and resource endowments, which have not been systematically studied. With the increase in scale and standardization of dairy farming in China, the conditions for the application of MF are available.

The relationship between feed prices and raw milk prices varies among countries or regions, Thus, analyzing the relationship between feed prices and raw milk prices in such countries or regions is essential for constructing and applyin MF models. Zhang and Dong (2017) concluded that EU raw milk prices have a significant impact on raw milk prices in both the United States and China, In contrast, the Chinese raw milk market is unable to influence the other markets, indicating the relative independence of raw milk prices in China. The dependence between raw milk prices and feed prices, in turn, helps to stabilize the dairy market (Bozic et al., 2012), Maintaining a long-term relationship between the two prices, with feed prices as the dominant variable, can provide a reasonable price forecast for the future (Gunnar et al., 2015).

This study aims to construct an appropriate milk-feed ratio model based on official statistics and research data of large-scale dairy farms (with over 100 dairy cows) in 26 provinces/autonomous regions/municipalities (from now on referred to as provinces) in China during 2018-2020. It first analyses the relationship between feed and raw milk prices in China. Then, it systematically constructs an MF model for the whole country and different production areas, which is the main objective of this study. Finally, it analyses the changes in MF for the whole country and different production areas and draws key research conclusions.

METHODS AND DATA

Test model

Considering the higher reliability of Vector Autoregressive Model (VAR) models compared to single equation models (Gujarati, 2004; Enders, 2010), and the non-stationarity of the variables examined, we used cointegration analysis to test the long-run correlation between raw milk prices and the prices of corn, soybean meal, alfalfa and corn silage, while Granger causality was tested using the Wald statistic based on the vector error correction model (VECM) (Shamsudin,2011), The formula is shown below:

$$X = \sum_{i=1}^{n} A_i \Delta X_{t-i} + \alpha\beta' X_{t-1} + \varepsilon \quad (1)$$

Where $X=(P_{milk_t}, P_{corn_t}, P_{soybean_t}, P_{alfalfa_t}, P_{corn\ silage_t})$ denotes the system vector with five variables, A_i denotes the coefficient matrix, α denotes the coefficient vector of the error correction term, β denotes the covariance vector, and $\beta' X_{t-1}$ denotes the error correction term.

The above vector error correction model is the general form of the test model, and for the specific test model only one of P_{milk} and various feed prices (P_soybean, P_corn, P_alfalfa, P_corn silage) are included.

MF model

The milk-to-feed price ratio, as defined by International Farm Comparison Network (IFCN), is the milk price divided by the price of purchased feed. In simplified form, it indicates how much feed (in kilograms of concentrate) is possible for a farmer to buy with the proceeds from one kilogram of milk. This study, drawing on the existing research on the main influencing factors in the construction of the MF model and the calculation method of the feed weight, combined with the actual situation in China, constructs the Chinese MF model. The expression of feed price in China's MF model is:

$$feed\ price, ¥/kg = \sum_{i=1}^{n}\left[(P_i, ¥/kg)\cdot\alpha_i\right] \quad \sum_{i=1}^{n}\alpha_i = 1 \tag{2}$$

Among them, $i = 1,2,...,n$ represents different types of feeds including corn, soybean meal, corn silage and alfalfa, and α represents the standardized proportion of the selected four feeds in the cost of dairy cow breeding, that is, feed weight; P_i represents the monthly price of feed. The formula is as follows:

$$\alpha = \frac{(X_C, ¥/kg)}{(feed_C, ¥/kg)} \times 100\% \tag{3}$$

Among them,$i = 1,2,...,n$ respectively represent different types of feed,X_i represents the cost of different feeds for a cow in one month, and $f\ eeds_C$ represents the total monthly feed cost of a cow. According to the research conclusions of previous scholars, $f\ eeds_C$ accounts for 60%-70% of the cost of dairy cow breeding, which is very representative (Somogyi et al., 2001; Yu et al., 2010; Ma, 2010). In summary, the expression of the MF model is:

$$MF = \frac{(milk\ price, ¥/kg)}{(feed\ price, ¥/kg)} \tag{4}$$

Where, milk price represents the price of raw milk, and feed price represents the price of feed.

According to the MF value, IFCN divides the MF into three levels – low, medium, and high: (1) an MF value lower than 1.5 is categorized into the low level, where dairy farming is in a loss state; (2) an MF value between 1.5 and 2.5 is at the medium level, where dairy farming can achieve profitability; and (3) an MF value greater than 2.5 reaches the high level, where dairy farmers can increase profit.

Data description

The data of this research comprise farm survey data and official statistics. The survey data mainly came from the targeted monitoring across 26 provinces of China in 2018, 2019, and 2020. The study calculated the MF in different production areas. Based on the National Dairy Development Plan 2016-2020, the 26 provinces were classified into five major dairy production areas: North (Hebei, Henan, Shandong, and Shanxi), Northeast-Inner Mongolia (Inner Mongolia, Heilongjiang, Liaoning, and Jilin), areas around the big cities (Beijing, Shanghai, and Tianjin), Northwest (Xinjiang, Gansu, Shaanxi, and Ningxia), and South (Anhui, Jiangsu, Zhejiang, Hubei, Hunan, Guangdong, Guangxi, Sichuan, Fujian, and Yunnan). The number of survey samples in each production area is shown in Table 1.

The survey collects farm cost information, including feed cost, daily consumption, depreciation and other costs. Feed mainly includes two categories: roughage and concentrate feed. The monthly average daily feeding amount is counted for dry dairy cows and lactating cows. The concentrate feed includes new feed, intermediate feed, corn, corn flakes, and soybean meal. Feeding amount of cottonseed meal, Distillers Dried Grains with Solubles (DDGS), bran, corn husk powder, soda, premix, concentrated feed and other feeds. Roughage includes silage corn, alfalfa, oat grass,and chinensis. Feed cost mainly counts the feed expenditures of different types of pastures in one month, it also includes the current prices of different feeds. Daily expenditures mainly counts the labor monthly costs of costs, water and electricity, medical and epidemic prevention, transportation, and other pasture costs. Depreciation denotes the cost of adult cows, infrastructure and equipment depreciation in the pasture in one month, Other costs mainly include the cost of loan interests, land costs, dairy cow death losses, equipment maintenance fees, and other pasture costs in one month.

Table 1: The survey samples of large scale dairy farms in different production areas from 2018 to 2020

Dairy production area	2018	2019	2020
North production area	79	60	66
Northeast Inner Mongolia production area	63	53	54
Production area around the big cities	45	57	56
Northwest production area	47	41	47
South production area	40	44	45
Total	274	255	268

The price data used in calculating the MF comes mainly from the Ministry of Agriculture and Rural Affairs, the National Animal Husbandry Station, and the Tianxia Granary Network. This study mainly counted the monthly price data of raw milk and main feed in the country and 26 provinces from 2010 to 2020. A total of 9,642 valid data were collected. The price statistics of raw milk in the country and 26 provinces come from the Ministry of Agriculture and Rural Affairs, the price data of corn and soybean meal come from the National Animal Husbandry Station, and the price of alfalfa comes from the Tianxia Granary Network. Since there is no official data on the price of silage corn, the monthly price data of silage corn in this article were collected by our research team in 2018, 2019, and 2020. It is feasible to use the purchase price of silage to represent the price of silage corn. This is because, according to the breeding habits of pastures, the designed storage capacity of silage silos is no less than eight months, and most ranches purchase silage in large quantities each year, enough to feed the ranch for more than a year.

ANALYSIS OF THE RELATIONSHIP BETWEEN RAW MILK PRICES AND FEED PRICES IN CHINA

Trends in raw milk prices

In recent years, raw milk prices in China have fluctuated frequently and significantly. The overall performance presents a seasonal U-shaped fluctuation, falling first and then rising (Fig. 1). Raw milk prices declined from 2015 to 2018, with a cumulative decline of 12.53%, and gradually rebounded in 2018. In recent years, the international economy has slowed, the international market consumption has been downturned, international milk prices have declined, and China's dairy imports have surged. Consequently, China's domestic milk market has been severely affected, and its domestic supply of raw milk exceeds demand.

From June 2018 to December 2020, there was a rapid rise in raw milk prices in China, and in just over a year, it recovered to the highest milk price level in the past five years. The 2018 trade friction between China and the U.S. blocked the import of soybeans, alfalfa grass and other major feeds, tightened the domestic feed supply, and raised feed prices, increasing breeding costs and milk prices. With the increasing consumption of dairy products in China, the demand for raw milk will further increase, and raw milk prices will still have upward pressure. The increased consumer demand for dairy and other nutritional products due to the COVID-19 pandemic, coupled with reduced imports and tightened supply, push raw milk prices further up.

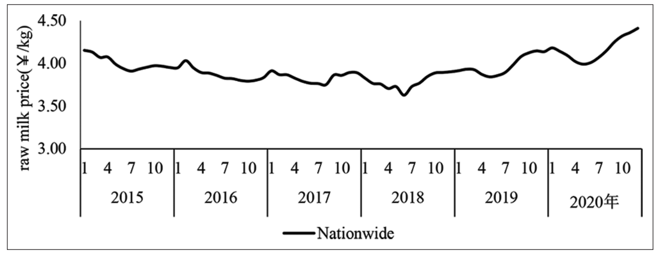

Fig 1. China's raw milk price trend from January 2015 to December 2020. Data source: Ministry of Agriculture and Rural Affairs of China(2021).[4]

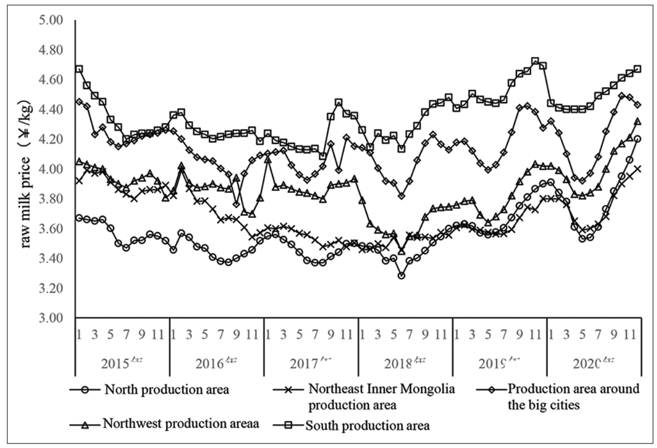

Fig 2. The price trend of raw milk in the five major dairy production areas from January 2015 to December 2020. Source: Ministry of Agriculture and Rural Affairs of China(2021).[5]

Raw milk price fluctuations in China are a composite of raw milk price fluctuations in various production areas. Raw milk prices vary among regions due to the differences in economic development, residents' income level, per capita consumption level, market supply and demand and other factors, The raw milk price is highest in the South production area, followed by the production area around the big cities. The lowest raw milk price is in the North production area, and the Northwest's price is close to the national average (Fig. 2). China's dairy market is well developed with fast price transmission between regions, leading to similar price fluctuation trends across production areas. Price fluctuations in each region are the main reason for national raw milk price fluctuations.

Granger test of raw milk price and feed price in China

This paper used five methods simultaneously to conduct unit root tests, including (1) Andrew Levin, Chen-Fu Lin, Chia-Shang James Chu (LLC), (2) Breintung, (3) Kyung So

4 Data source from the National Important Agricultural Market Information Platform(http://ncpscxx.moa.gov.cn/#/multipleAnalysis?item=2).

5 Data source from the National Important Agricultural Market Information Platform(http://ncpscxx.moa.gov.cn/#/multipleAnalysis?item=2).

Im, Hashem M Pesaran, Yongcheol Shin (IPS), (4) ADF-Fisher, and (5) PP-Fisher. The horizontal and first-order difference values of the price variables of national raw milk, corn, soybean meal, silage corn, and alfalfa grass all contain intercept and time trend terms, Therefore, the unit root test for them was also chosen as a test model that contains intercept and time trend terms.

The unit root tests results showed that only the LLC test rejected the original hypothesis of the existence of a unit root in P_{milk}, All other four methods did not rejected the hypothesis and therefore judged the existence of a unit root in P_{milk}. Similarly, except for the Breituin test and IPS test that rejected the original hypothesis of the existence of unit root of P_{bean}, the other three methods did not reject such a hypothesis. They therefore determine the existence of unit root of P_{bean}. The results of the test on P_{corn}, $P_{alfalfa}$, and $P_{corn\ silage}$ found that the original hypothesis of the existence of a unit root, confirming the existence of a unit root. The first-order difference series of P_{milk}, P_{bean}, P_{corn}, $P_{alfalfa}$ and $P_{corn\ silage}$ were tested for smoothness, which found that none of them had unit roots, Therefore, the five variables of P_{milk}, P_{bean}, P_{corn}, $P_{alfalfa}$ and $P_{corn\ silage}$ in China's dairy farming process were all first-order single-integer variables (Table 2).

The unit root test of the time series data indicated that the prices of national raw milk price, soybean meal price, corn price, silage corn price, and alfalfa grass price are first order single integers, Thus, there might be a cointegration relationship between raw milk prices and the prices of soybean meal price, corn price, silage corn price, and alfalfa grass. The study used the Pedroni test to further verify the cointegration relationship (Table 3).

According to the conclusion of Pedroni (1996), *PanelADF* and *GroupADF* tests are the best, *panel* υ and *group* ρ tests are the worst, and the others are in the middle, This order should be used as the basis for judgment when the test results are inconsistent. Since all the test results were inconsistent to varying degrees, the criteria of Pedroni's (1996) conclusions were used. When testing the relationship between P_{milk} and P_{bean}, P_{milk} and P_{corn} as well as P_{milk} and $P_{alfalfa}$, PanelADF and GroupADF rejected the hypothesis of "no cointegration" at the 1% significance level. P_{milk} and $P_{corn\ silage}$ reject the original hypothesis of "no cointegration" at the 10% level of significance. Therefore, there is a long-run covariance between P_{milk} and P_{bean}, P_{milk} and P_{corn}, P_{milk} and $P_{alfalfa}$, as well as P_{milk} and $P_{corn\ silage}$.

Cointegration tests of time series data proved that soybean meal prices and corn prices both had a long-term cointegration relationship with raw milk prices. The Granger causality test further analyzed the relationships, as shown in Table 4.

P_{bean} was the Granger cause of P_{milk} at the 1% significance level of significance, P_{corn} and $P_{alfalfa}$ were the Granger cause of P_{milk} at the 5% level and $P_{corn\ silage}$ was the Granger cause of at was 10% level of significance during 2010-2020. As the feed mix for dairy farming continues to be adjusted, alfalfa grass and maize silage are becoming an important part of the feed for more and more dairy farms. The level of standardization and scale of dairy farming is increasing, and the impact of corn, soybean meal, corn silage, alfalfa and other major feed prices on the raw milk became increasingly significant (Table 4).

CONSTRUCTION AND APPLICATION OF MF MODEL

Selection of feed types in the MF model

The main difference in constructing MF models in different countries or regions lies in determining feed types in feed prices, Three factors should be considered when selecting feed types: (1) Is it relatively indispensable in the dairy cow ration formula, and does it accounts for a relatively high proportion of the total feed cost? (2) Is it widely used in the entire area? and (3) Is price

Table 2: Results of unit root test for time series data of each variable

variable	(1) LLC	(2) Breituin	(3) IPS	(4) ADF-F	(5) PP-F
P_{milk}	-1.322	2.112	-1.917	28.355	1.776
P_{bean}	-0.226	3.985	-1.824	28.345	7.325
P_{corn}	-0.788	-1.232	0.908	20.923	14.991
$P_{alfalfa}$	-1.119	3.782	-1.267	29.443	0.876
$P_{corn\ silage}$	-0.178	-3.345	0.123	23.343	12.234
ΔP_{milk}	-12.298**	-2.214***	-9.876***	23.125**	35.876***
ΔP_{bean}	-13.764***	-3.347***	-14.561***	45.242**	28.870***
ΔP_{corn}	-12.227***	-9.768***	-14.345***	35.267**	25.231***
$\Delta P_{alfalfa}$	-22.899***	-4.450***	-18.229***	35.210**	22.671***
$\Delta P_{corn\ silage}$	-16.545***	-19.298***	-21.980***	23.87**	15.650***

(1) ***, ** denote significant at the 1% and 5% levels; (2) Δ denotes the first-order difference of the variable; (3) the optimal lag in the unit root test process is determined according to the Akaike Information Criterion (AIC) and the Schwarz Criterion (SC).

Table 3: Results of co-integration test for raw milk, corn, soybean meal, alfalfa grass, and silage corn prices

Relations	*panelυ*	*panel ρ*	*panelPP*	*panelADF*	*group ρ*	*groupPP*	*groupADF*
P_{milk} and P_{bean}	4.323 (0.030)*	2.221 (0.100)*	2.671 (0.003)***	-0.872 (0.091)***	2.219 (0.001)***	2.787 (0.000)***	1.337 (0.019)***
P_{milk} and P_{corn}	-0.298 (0.092)*	2.341 (0.002)**	3.989(0.000)**	2.712(0.000)***	4.981 (0.021)***	6.910 (0.003***	5.212 (0.000)***
P_{milk} and $P_{alfalfa}$	1.422 (0.143)*	1.768 (0.129)	2.672 (0.021)*	0.299 (0.019)***	3.879 (0.012)**	2.091 (0.002)***	0.120 (0.271)***
P_{milk} and $P_{corn\ silage}$	0.208 (0.123)	-0.045 (0.251)	0.708 (0.122)	-2.988 (0.096)*	0.991 (0.012)*	2.198 (0.127)	-0.901 (0.09)*

***, **, and * indicate significant at the 1%, 5%, and 10% levels.

Table 4: The test of the relationship between soybean meal, corn and alfalfa grass prices and raw milk prices

Original Assumptions	$\Delta P_{bean\,t-1}$	$\Delta P_{bean\,t-2}$	$\Delta P_{corn\,t-1}$	$\Delta P_{corn\,t-2}$	$\Delta P_{alfalfa\,t-1}$	$\Delta P_{alfalfa\,t-2}$	$\Delta P_{beansilage\,t-1}$	$\Delta P_{beansilage\,t-2}$	Conclusion
F1	0.009**	0.040***	-	-	-	-	-	-	NO
F2	0.358	-0.068	-	-	-	-	-	-	YES
F1	-	-	0.025**	0.041**	-	-	-	-	NO
F2	-	-	0.232	-0.171	-	-	-	-	YES
F1	-	-	-	-	0.041	0.080**	-	-	NO
F2	-	-	-	-	0.363	0.078	-	-	YES
F1	-	-	-	-	-	-	0.081*	0.072*	NO
F2	-	-	-	-	-	-	0.920	0.077	YES

***, **, and * indicate significant at the 1%, 5%, and 10% levels.

information easy to access? Therefore we normally choose the types of feed with official price statistics, which can more accurately and timely measure the MF in each area. According to the statistics of "National Agricultural Product Cost and Benefit Data Collection 2018" and "National Agricultural Product Cost and Benefit Collection 2019", feed costs account for 64.45% of the total cost of dairy cow breeding in China. In some recent literatures, the share of feed cost in operating costs has been calculated to be between 48.65-65.30% (Santos, 2018; ÖRS and OĞUZ, 2019; Tapki, 2019), but in China 60-70% is more representative (Wang,2010). The feed costs in the production areas surrounding major cities - North China, Southern, Northwest and Inner Mongolia production areas - accounted for 70.07%, 67.25%, 65.09%, 64.76% and 63.75% of the total dairy farming costs, respectively.

According to the analysis of survey data, the average total cost of producing one kilogram dairy milk in China's large scale dairy farms (dairy cattle number >100) is 3.91 RMB, and feed cost of one kilogram of milk is 2.51 RMB. Feed is the main expenditure item of large scale dairy farms, accounting for 64.35% of the total cost on national average. Feed as a whole-process input is not only related to the quantity and quality of dairy cow production and the cost of dairy cow breeding. The daily consumption of large cale dairy farming costs 19.56%, of which labor costs account for the highest proportion; Depreciation costs are mainly the depreciations of equipment, infrastructure, and adult cows, account for about 11.43% of the monthly cost of dairy cows. Insurance premiums, loan interest, maintenance fees and other costs account for about 5.32% of the breeding costs (Table 5).

Table 5: 2018-2020 National Large scale Dairy Cow Breeding Cost Composition Situation (%)

Cost type	Nationwide			
	2018	2019	2020	Average
The proportion of feed cost	63.17	64.12	65.15	64.35
The proportion of daily consumption	19.28	19.87	20.29	19.56
The proportion of depreciation	11.19	11.68	12.23	11.43
The proportion of other cost	7.19	6.76	3.21	5.32

Source: Farm survey data

There are significant differences in the cost composition of dairy farming in different production areas. The feed cost takes the highest proportion, with an average proportion of more than 60%, and the highest being 68.88%, which is a good proportion(Fig. 3). Corn, soybean meal, corn silage and alfalfa accounted for 49.36% of the total feed cost. They are the primary sources of protein and energy in the dairy cow's diet and can effectively reflect the changes in feed costs. Therefore, these four feeds were selected to calculate the comprehensive feed price in China's MF model. Due to differences in resource endowments and economic conditions in different dairy production areas, there are obvious differences in the diet structure of dairy cows, and the weight of feed prices in the MF model of each dairy production area is bound to be different (Table 6).

Determination of the cost weight of forage types

The determination of the cost weights of feed types is the key to construct the MF model. Based on the proportion of the selected feed types, the cost weights of the four feed types are further standardized to transform the original data into non-dimensional indicators. Table 7 displays the cost weights of corn, soybean meal, corn silage, and alfalfa after standardized treatment in the country and in various dairy production areas. The weights of corn, soybean meal, corn silage and alfalfa in China are 27%, 17%, 30% and 26% respectively, which are significantly different from the weights of corn, soybean and alfalfa in the US milk ratio model (51%, 8% and 41% respectively[6]), mainly due to differences in resource endowment and feeding habits between countries and regions.

Construction of MF model

According to the formula of MF, based on the standardized treatment results of the cost weight of the above feed types, the nationwide MF model can be constructed as follows:

$$MF_1 = \frac{P_{milk}}{P_X \times 27\% + P_Y \times 17\% + P_Z \times 30\% + P_M \times 26\%} \quad (5)$$

Where, P_X, P_Y, P_Z, P_M, P_{milk}, respectively represents the price of corn, soybean meal, corn silage, alfalfa and raw milk. The feed price in the national MF model is the composite average price of corn, soybean meal, corn silage and alfalfa, weighing 27%, 17%, 30% and 26%, repectively. This is different from developed countries such as the United States. The feed price in the US MF model is a composite average price of corn, soybeans, and alfalfa weighing 51%, 8%, and 41%, respectively. This is mainly due to the difference in the diet structure of Chinese and American dairy cows. The United States is the world's largest producer and exporter of corn and alfalfa, where corn and alfalfa account for a large proportion of its dairy cows' diets. However, half of the alfalfa supply for dairy cows in China highly depends on imports, and the corn supply is tight all over the country or in particular regions (Xian et al., 2015). In a balanced state, the proportion of alfalfa and corn in the dairy cow's diet is significantly lower than that of the United States.

6 Data source from Wolf's paper "Understanding the milk-to-feed price ratio as a proxy for dairy farm profitability" in 2010.

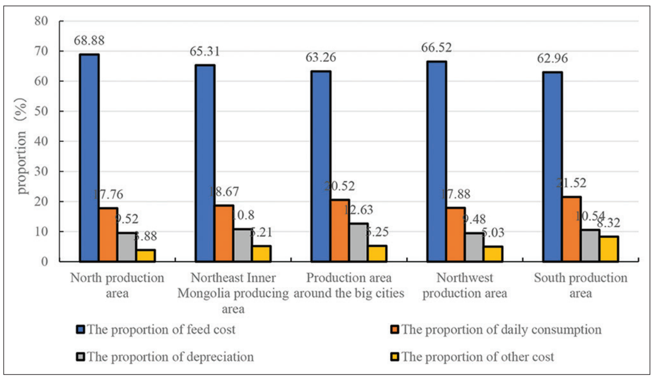

Fig 3. The proportion of different cost types in the total cost of large scale dairy farm. Source: Farm survey data.

Table 6: The proportion of the main forage cost of large scale dairy farm in the total feed cost (%)

Feed type	Nationwide	North production area	Northeast Inner Mongolia producing area	Production area around the big cities	Northwest production area	Southern production area
Corn	13.14	13.09	13.57	9.94	10.32	14.89
Soybean meal	9.15	10.69	7.56	7.53	7.33	5.97
Corn silage	14.31	14.34	16.26	15.07	14.49	13.79
alfalfa	12.76	14.81	11.16	11.46	12.47	9.82
cottonseed meal	2.77	3.42	2.64	2.27	2.12	1.17
DDGS	1.53	1.71	1.85	1.44	0.89	3.01
Bran	0.34	0.40	0.32	0.30	0.26	1.90
Premix	5.41	3.66	3.61	3.47	0.58	5.24
Cottonseed	5.70	3.64	2.91	3.39	3.05	2.91
Concentrated feed	20.99	14.20	19.09	16.21	16.50	15.96
Chinensis	1.49	1.66	2.52	1.28	1.36	0.48
Oat grass	6.25	2.48	5.78	2.48	3.58	2.48

Source: Farm survey data

Table 7: Weight of main feed cost of large scale dairy farm (%)

feed type	Nationwide	North production area	Northeast Inner Mongolia producing area	Production area around the big cities	Northwest production area	Southern production area
Corn	27	25	28	23	24	32
Soybean meal	17	20	16	17	16	13
Corn silage	30	27	33	34	33	33
alfalfa	26	28	23	26	27	22
Total	100	100	100	100	100	100

Source: Farm survey data

The MF model of the five dairy production areas is as follows. The same symbols indicate the same meanings in the following formulas.

MF Model in the North production area:

$$MF_2 = \frac{P_{milk1}}{P_X \times 25\% + P_Y \times 20\% + P_Z \times 27\% + P_M \times 28\%} \quad (5)$$

MF model in the Northeast-Inner Mongolia production area:

$$MF_3 = \frac{P_{milk2}}{P_X \times 28\% + P_Y \times 16\% + P_Z \times 33\% + P_M \times 23\%} \quad (6)$$

MF Model in the Production area around the big cities:

$$MF_4 = \frac{P_{milk3}}{P_X \times 23\% + P_Y \times 17\% + P_Z \times 34\% + P_M \times 26\%} \quad (7)$$

MF Model in the Northwest production area:

$$MF_5 = \frac{P_{milk4}}{P_X \times 24\% + P_Y \times 16\% + P_Z \times 33\% + P_M \times 27\%} \quad (8)$$

MF Model in the South production area:

$$MF_6 = \frac{P_{milk5}}{P_X \times 32\% + P_Y \times 13\% + P_Z \times 33\% + P_M \times 22\%} \quad (9)$$

Due to the difference in resource endowments, the diet structure of the large scale dairy farms is different among the five major dairy production areas, and the MF model parameters are correspondingly different. The feed price in the MF model in the North area is the comprehensive price of corn, soybean meal, corn silage, and alfalfa with weights of 25%, 20%, 27%, and 28%, respectively. The feed price in the MF model in the Northeast-Inner Mongolia area is the comprehensive price of corn,soybean meal, Corn silage and alfalfa, with weights of 28%, 16%, 33%, 23%, respectively. In the area around the big cities, the feed price in the model is the comprehensive price of corn, soybean meal, corn silage, and alfalfa with weights of 23%, 17%, 34%, and 26%, respectively. The feed price in the Northwest area's MF model is the comprehensive price of corn, soybean meal, corn silage, and alfalfa, which weighted 24%, 16%, 33%, and 27%, respectively. In the South area's MF model, the feed price is a comprehensive price of corn, soybean meal, corn silage, and alfalfa with weights of 32%, 13%, 33%, and 22%, respectively. The weight of corn is significantly higher in the Northeast-Inner Mongolia and South areas than in the North area, Northeast-Inner Mongolia area, and the area around the big cities. The weight of soybean meal in the North area is significantly higher than that in the Northeast-Inner Mongolia area and the area around the big cities. The weight of soybean meal in the South area is significantly lower than in the other four production areas. The weight of corn silage is significantly lower in the North area than in the Northeast-Inner Mongolia area, the Northwest area, the production area around the big cities, and the South area. The weight of alfalfa in the Northwest area and the production area around the big cities is significantly higher than that in the Northeast-Inner Mongolia and South areas.

Measurement of MF

Measurement of MF at national level

Based on the national MF model constructed above, the overall level of China's MF was estimated. The overall MF in China has shown an increasing trend in the past three years (Table 8). The average national MF from 2018 to 2020 is 2.11, which means that the income generated from one kilogram of raw milk is 2.11 times the feed cost. According to the monthly MF, it can be seen that due to the seasonal variation of raw milk (Wang and Li, 2010), the MF is lower in 2-3 quarters each year, showing a "U" shaped change on an annual cycle. The MF was 1.99 in 2018, 2.09 in 2019, and 2.24 in 2020. The increasing trend is mainly due to the withdrawal of free-range farmers in China in recent years, the reduction of dairy cows, the tight supply of raw milk, and the increased in consumption of dairy products. The price of raw milk remains high. According to statistics from the Ministry of Agriculture and Rural Affairs of China[7], compared with 2018, the price of raw milk in 2020 will increase by 20.5%. At the same time, although the price of corn, soybean meal, corn silage, alfalfa and other feeds have also increased, the increase is relatively small, resulting in an increased MF. According to the definition of the IFCN (see section 2.2), China is at a medium-level MF, and most large scale dairy farms are profitable.

Measurement of MF in different producing areas

There were significant differences in the MF among different production areas (Fig. 4). The South production area has the highest MF, with an average of 2.42 in the

7 Data source from the National Important Agricultural Market Information Platform(http://ncpscxx.moa.gov.cn/#/multipleAnalysis?item=2).

Table 8: Monthly change of dairy feed ratio in China from 2018 to 2020

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
2018	2.10	2.07	2.04	1.97	1.98	1.96	1.93	1.89	1.96	1.95	1.97	2.03
2019	2.03	2.07	2.10	2.08	2.06	2.01	2.00	2.03	2.12	2.17	2.20	2.23
2020	2.34	2.31	2.28	2.22	2.16	2.19	2.20	2.20	2.24	2.26	2.25	2.27

Table 9: MF of the five dairy producing areas from 2018 to 2020

Dairy production area	Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
North production area	2018	1.99	1.96	1.91	1.82	1.88	1.85	1.86	1.86	1.84	1.83	1.84	1.90
	2019	1.91	1.92	1.96	1.96	1.93	1.87	1.88	1.74	1.86	1.94	1.97	2.04
	2020	2.08	1.96	1.93	1.85	1.85	1.87	1.97	1.98	2.04	2.07	2.07	2.15
Northeast Inner Mongolia producing area	2018	2.14	2.12	2.12	1.99	2.09	2.05	2.07	2.02	2.01	1.95	1.98	1.99
	2019	2.07	2.09	2.10	2.11	2.08	2.02	2.02	2.02	2.21	2.25	2.22	2.29
	2020	2.28	2.23	2.20	2.10	2.03	2.04	2.13	2.08	2.14	2.15	2.17	2.20
Production area around the big cities	2018	2.35	2.33	2.21	2.11	2.09	2.1	2.07	2.11	2.16	2.15	2.14	2.18
	2019	2.32	2.33	2.42	2.33	2.35	2.21	2.27	2.37	2.44	2.48	2.45	2.39
	2020	2.41	2.34	2.27	2.14	2.13	2.16	2.2	2.32	2.36	2.37	2.39	2.40
Northwest production area	2018	2.19	2.09	2.05	1.97	2.02	1.95	1.96	1.97	2.03	2.05	2.06	2.07
	2019	2.05	2.06	2.13	2.13	2.09	2.01	2.06	2.14	2.20	2.23	2.22	2.22
	2020	2.27	2.27	2.23	2.15	2.13	2.17	2.26	2.26	2.32	2.34	2.35	2.36
South production area	2018	2.47	2.42	2.42	2.30	2.38	2.38	2.40	2.42	2.42	2.41	2.4	2.44
	2019	2.39	2.41	2.49	2.48	2.46	2.40	2.42	2.48	2.51	2.52	2.55	2.54
	2020	2.39	2.32	2.32	2.30	2.29	2.30	2.35	2.38	2.40	2.45	2.50	2.51

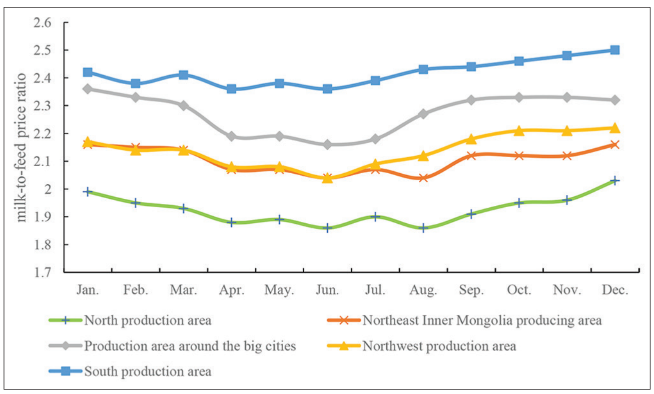

Fig 4. Average monthly MF of five dairy producing areas during 2018-2020.

past three years, indicating that the income per kilogram of milk in this is 2.42 times that of feed cost. This is mainly due to the high raw milk price in the South area, which increases dairy farms' economic income. The average MF of the production area around the big cities is 2.27. This production area has a significant consumer demand for dairy products, a small milk supply, high breeding costs, and a high price of raw milk. The average value of the Northeast-Inner Mongolia and Northwest production areas is 2.12, which is close to the national average., These are traditional pastoral areas with low consumption, large milk production, low raw milk price, rich feed resources, low breeding cost and good overall breeding benefits. The MF in the North area is the lowest, with an average value of 1.93. This is also an advantageous area for dairy farming in China as it has a large stock of cows and a sufficient milk supply, However, in this area, the consumption level is low, the raw milk price is relatively low, and its feed price is relatively high, leading to a low MF (Table 9).

CONCLUSION

There is a long-term cointegration relationship between raw milk prices and the prices of corn, soybean meal, corn silage, and alfalfa in China. Moreover, with the increasing standardization and scale of dairy farming, the impact of corn, soybean meal, corn silage, alfalfa, and other major feed prices on the raw milk market has become more significant. Currently, the average feed cost per kilogram of milk is 2.51 RMB for large-scale dairy farms in China, accounting for 64.32% of its total cost of production. The cost of corn, soybean meal, corn silage, and alfalfa accounts for 49.36%. The four feeds are the primary sources of protein and energy in dairy cow diets; thus, their prices can effectively reflect the changes in feed costs. These four feeds were therefore selected to calculate the comprehensive feed price, and the price weights of corn, soybean meal, corn silage, and alfalfa were found to be 27%, 17%, 30%, and 26%, respectively. In recent years, China's MF has shown an upward trend year by year. The national MF has remained above 1.89, and the MF of the five major dairy production areas has remained above 1.83. The MF showed a U-shaped cyclical pattern within one year. According to the definition and classification by IFCN, the current MF values of large-scale dairy farms in China and the five major dairy production areas are already at a medium level. This means that China's large-scale dairy farms have begun to gain profitability. Due to the apparent difference in resource endowment and dairy cow ration structure, MF varies significantly between production areas.

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Authors' contributions

All authors contributed to the writing of the article. Dong Xiaoxia was responsible for data acquisition and article structure determination; Liu Hao wrote, translated, and submitted the article and wrote all correspondence and revisions; Peng Hua handled data and graphs; Zhang Chao did the language spelling check.

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Declaration of competing interest

The authors declare no conflict of interest.

Informed consent

Written informed consent was obtained from all study participants.

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