The Dynamics of China's Mutton Price Fluctuations Under Extreme Events

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Abstract. The notion of price instability has garnered renewed interest because of ongoing swings in agricultural prices in nations like China. We investigate the root cause of price volatility in the mutton market in China. To this purpose, we develop a theoretical model to explain endogenous price changes in the Chinese mutton supply chain by using information from our fieldwork and estimates from unobserved component models. We use vector auto regressions and weekly data on sheep and mutton prices in China to derive hypotheses from our theoretical model that can be tested under conventional assumptions. Our empirical results are consistent with those of our theoretical model, and the evidence of endogenous dynamics in observed prices is resistant to different specifications and estimating techniques. We demonstrate with the aid of numerical simulations how empirically based parameterizations of our theoretical model can accurately represent the key elements of mutton price fluctuations in China. Our descriptive, empirical, and numerical studies have accumulated evidence that strongly supports the endogenous nature of price instability in China's mutton supply chain.

Keywords: Endogenous price fluctuation, Agricultural supply chain, mutton supply

1 Introduction

The health of the nation is highly dependent on how well the agricultural economy works. Above all, it is essential to ensure sustainable food security, employment and livelihoods for almost one-third of the world's population [1]. However, varied prices in agricultural products have a detrimental effect on the stability and growth of the economy of nations. The negative consequences of agricultural price instability on nations are amplified by inadequate storage facilities, disjointed agricultural supply chains, and restricted access to risk-sharing markets for farmers. As a result, farmers in these nations experience significant price risk and struggle with production planning results in social unrest and food insecurity [2].

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One of the most popular types of meat consumed by China's locals is mutton. China's mutton industry has grown quickly since the country's reform and opening, and its output has significantly increased. For years, China has ranked first in the world for mutton production [3]. The amount of mutton produced nationally in 2019 was 4.8752 million tons. Nonetheless, the business still faces some issues that limit its ability to compete.

Mutton prices have shown a shifting pattern over the last few years due to the steadily rising demand for the meat. As a result, it is extremely useful to study what factors contribute to the ups and downs of China's mutton market. The extant literature shows that numerous researchers have investigated the topic of mutton price volatility from both theoretical and empirical angles [4]. Feed factors, including price fluctuations and feeding costs, influence the cost of raising mutton. The key factors influencing mutton pricing in China are supply, feeding expenses, and consumer demand. Otherwise, reference [5] it is found that income level and mutton pricing significantly affect per capita mutton ingesting, while the weight of the carcass and number of sheep have a major influence on China's veal output. External conventional elements that affect the volatility of the mutton price include demand and supply, as well as the cost of agriculture and related items, alternatives, and population size [4].

According to research, numerous studies have investigated the topic of mutton price volatility from both within and outside the industry. For the last decade, in China's mutton supply chain, the continuous price swings have deterred investments in goat meat production and caused thousands of farmers facing bankruptcy [6]. This study employs data from the endogenous literature on agricultural pricing to undertake fieldwork, based on a theoretical model, to show that price volatility in the Chinese mutton supply chain is, in fact, endogenous. We provide data from numerical simulations and describe the results of hypothesis testing.

China is skilled at producing and consuming mutton, according to reference [7]. China's mutton industry has grown quickly since the country's reform and opening, and its output has significantly increased. The growth of the China mutton business has been steady, and it has now established itself as a key pillar of animal husbandry, driven by the country's economic development and improvements in the tourism sector. Nonetheless, the business still faces some issues that limit its ability to compete. This study initially creates an indicator system for the competitiveness of the mutton business based on Michael Porter's diamond model. After that, a thorough examination of the competitive landscape is used to explain the current state of the Chinese mutton sector. Lastly, this report makes some recommendations for boosting the China's mutton industry's industrial competitiveness.

2 Literature Review

Agricultural development and food security are among the central issues of concern of policy makers in many developing countries, including China. Nonetheless, there are regional and national variations in the amount of progress gained in emerging nations. When researching the growth of agriculture, China is one of the most fascinating cases to look at. In the last 25 years, agriculture has grown roughly four times greater than the population expansion. Due to the economy's stabilization and liberalization, China requires continuing agricultural imports, which contradicts some experts' prediction. Despite more than 20 years of reforms and quick growth, China is still a net exporter of agricultural and food goods.

Yet, past successes do not ensure increased agricultural production or a secure supply of food in the future. Although most recent studies have determined that China's increased food and grain imports won't cause the rest of the globe to go hungry, China still has a significant problem ahead to feed its expanding population in the future while also continuously raising rural income. The level of China's ability to feed itself in the future will depend on agricultural productivity growth and the availability of resources (such as water and land) for agricultural production, as rapid industrialization and urbanization will cause competition for resources between the agricultural and non-agricultural sectors.

2.1 **Agriculture in China**

Due to geographical and climatic considerations, only 10% of China's total land area is suitable for farming. Much progress has been made in water conservation; of this, slightly more than half is in unirrigated areas, and the remaining percentage is split almost evenly between irrigated and paddy fields. However, there are geographical variations in the quality of agricultural soil, and many areas suffer serious dangers from environmental problems including erosion, drought, and floods.

Another most significant part of agricultural production is animal husbandry. China boasts huge herds of sheep and cattle, and it is the world's top producer of pigs, chickens, and eggs. More emphasis has been placed on raising the productivity of livestock since the mid-1970s.

Major agricultural products: China produces the most food in the world, but only 10% of its total geographical area is available for agriculture. About 20% of the world's population is fed by China's agricultural land, which accounts for 10% of the world's total agricultural land. Only about 1.2% (116,580 sq km) of this approximately 1.4 million sq km of fertile land is permanently used for agriculture, of which 525,800 sq km is irrigated [8]. About 200 million households share land, and each household owns, on average, only 0.65 hectares (1.6 acres).

Livestock: Sheep, goats and poultry are the most prevalent types of livestock in China. Sheep, goats, and camels are kept by nomadic herders in rural western China. Yaks are raised in Tibet as a source of food, fuel, and housing. Although about 92.3% of the adult population suffers from some form of lactose intolerance, cattle, water buffalo, horses, mules, and donkeys are also raised in China, and dairy consumption has recently been encouraged by the government.

2.2 Inefficiencies in the agricultural market

The Chinese agricultural sector still faces some obstacles despite high output increases. Farmers lacking knowledge in numerous provinces, including Shandong, Zhejiang, Anhui, Liaoning, and Xinjiang, frequently struggle to sell their agricultural products to consumers.

The inefficiencies in the market mechanisms between producers and end consumers are highlighted by these information and transportation issues, making it difficult for producers to benefit from the rapid growth of the rest of the Chinese economy. Due to the low profit margin, they are unable to invest in the agricultural inputs (such as machinery, seeds, fertilizers, etc.) that would increase their production and boost their living standards, which would help the entire Chinese economy. As a result, more people move from rural areas to the cities, which already struggle with urbanization.

Governmental influence: China entered into the World Trade Organization (WTO) on December 11, 2001, which resulted in the reduction or elimination of tariffs on the majority of China's agricultural exports and was a significant driver of greater global commerce. But the liberalization of China's agricultural trade has lagged, and its markets are still mostly inaccessible to foreign businesses. It is assumed that China would turn into a regular net importer of food if its agricultural markets were opened due to its sizable and expanding population, thereby upsetting the global food market.

2.3 Extreme Events

The confrontation between Russia and Ukraine, the Covid-19 epidemic, and infectious diseases are just a few of the dramatic events. The possible vulnerabilities in the food supply chain have come to light because of these kinds of extreme instances as proposed by previous study in reference [9]. For instance, the COVID-19 pandemic had a negative impact on many facets of life and had a significant negative impact on the livestock business, including the supply chain and global production of mutton (see Fig. 1).

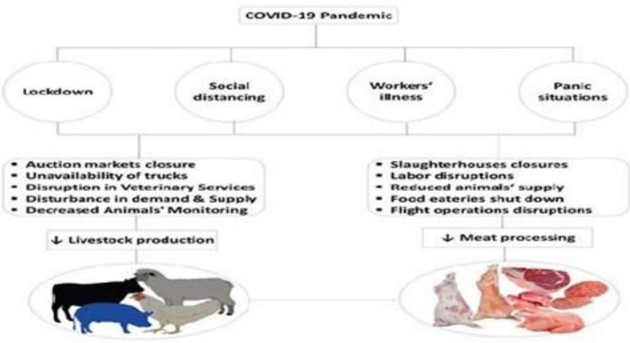


Fig. 1. Showing effect of COVID-19 on mutton supply chain and production.

3 Methods and Data Sources

3.1 Theoretical model

Using a stylized nonlinear cobweb-style model of the Chinese mutton supply chain, we will now proceed to generate hypotheses. Our theoretical model, which is based on the research from reference [10], considers important elements of the institutional environment, such as the interdependence of mutton marketers in a supply chain for mutton that is regulated by spot markets, lamb that is slaughtered for mutton, farmers' naive forecasts, and heterogeneity in terms of farmers' production costs and technologies (see Table 1). In order to construct the coupled nonlinear difference equations that characterize mutton price dynamics in our theoretical model, we recursively tackle the profit maximization problem of sheep farmers. In order to provide mutton price assumptions that can be empirically tested, this system of nonlinear equations is linearized.

Table 1. Showing the origin data of the mutton index system.

Third- class indicator	Inner Mongolia	Xinjiang	Shandong	Hebei	Sichuan	Henan	Gansu	Anhui	Hunan
No. of elevated sheep (10000)	6112	4318	1754	1228	1599	1682	1840	505	662
Mutton production (10000 ton)	104	58	36	30	27	26	23	17	15
Animal farming technical institutions (individual)	1202	1239	1664	1665	4271	1590	1509	1293	2120
Animal farming technician (person)	12306	14490	11186	10641	21471	13418	10702	5549	15404
Total population	2529	2445	10006	7520	8302	9559	2626	6255	6860
Ingesting level of residents	23909	16736	28535	15893	17920	17842	14203	17141	19418
Number of traveler (10000)	11646	10726	78000	57000	57000	66511	23905	63100	67323

Proposition: We create a discrete time dynamic model in which one week serves as the unit of time. It is thought that mutton is a non-storable commodity that is traded on active spot markets. We assume that farmers are profit-maximizing (risk-neutral) agents. The number of marketers and retailers is taken to be fixed, and market entry and exit dynamics are not considered. According to the results of the fieldwork, we presume farmers base their predictions of future prices on the current market. Convex cost functions capture falling marginal productivity in the short run, although farmers are assumed to have a fixed share of production technology. We consider farmer heterogeneity in terms of production costs and technology, so that small-scale farmers have cheaper input costs and less effective production methods than large-scale farmers. This presumption intuitively captures the trade-off that occurs in agricultural production between input costs and yields. But as we found, during our fieldwork, breeding sheep are still killed based on their limited productive lifespan (regardless of mutton pricing) and sold as mutton in markets. We utilize a deterministic function based on the life cycle of parent sheep for breeding to account for lamb produced from parent sheep breed in order to achieve more meaningful comparisons between observed and simulated data. We can incorporate some of the known long-run dynamics in our model. The last assumption is that the demand for mutton among retailers is declining.

3.2 Analysis

Lamb and sheep market-clearing prices in period t are indicated by the symbols p^{Ct} and p^{Bt}, respectively. Similarly, ^{qCi},t and ^{qBi},t indicate the output of farmers raising lamb and sheep during time t. ^{PSB}t is the amount of mutton harvested from the slaughter of parent stock that was culled during period t. The conversion rate of sheep into mutton is $0<k^{B}i<1$, according to the production technology used by the $_{i}$th sheep farmer. The conversion-rate of lumb into sheep, $0< {}_{k}C_i <1$, is what determines the mutton farmer's production technology.

Farmer types are indicated by the subscript i; for example, the letters i= L and i= S stand for large- and small-scale farmers, respectively. The average conversion rate for each type of farmer is represented by the numbers k^BL, k^BS, k^CL, and k^CS, where $k^BL > k^BS$ and $k^CL > k^CS$.

The number of lambs purchased at the start of the mutton production cycle is denoted by qCt in the cost function of the i th sheep farmer, which is represented as CBiqCt. The cost function of the ith sheep farmer is denoted by CCi qet, where qet is the quantity of lamb purchased at the beginning of the mutton production cycle. Convex functions C^Bi and C^Ci have $C^BL(q^C) > C^BS(q^C)$ for $8q^C$ and $C^CL(q^e) > C^CS(q^e) >$ for $8q^e$.

We can divide this multistage decision problem into a series of interrelated optimization problems due to the sequential pattern of manufacturing options in a mutton supply chain. This backward induction method makes it easier to analyze supply chains mathematically because it allows one to make assumptions about the upstream profit maximization problem's unknowable solution while still determining the downstream stage's best course of action [11]. As a result, we first infer price dynamics in the mutton market by working our way backwards, step by stage. The representative sheep farmer's profit-maximization dilemma at time t can be expressed as follows:

$$\text{Max } \pi i,t+6 : P^{\sim B}t+6q^Bi,t+6\ p^Ct\ q^Ci,t - C^Bi\ (q^Ci,t)$$

$$\text{s:t. } q^Bi,t+6= k^Bi\ q^C{}_{i,t.}$$

3.3 Empirical Hypothesis- (Endogenous dynamics in mutton Prices)

The literature lacks well-established methods for structural estimation of nonlinear cobweb models with potentially chaotic dynamics [8]. Furthermore, the absence of trustworthy data other than price data makes it impractical to apply structural estimating methodologies in LDCs' agricultural markets. As a result, we don't try to structurally estimate our nonlinear cobweb model's parameters. Rather, we adhere to the empirical strategy used by reference [12] as well as reference [13]. By using auto regression techniques to examine whether the dynamics of observed agricultural prices are consistent with the predictions of competitive storage models, they assess the empirical applicability of the theory of exogenous price variations. In a similar vein, we use our theoretical model as a framework to explore whether endogenous pricing dynamics occur in China's mutton markets.

$$\left\{ \begin{array}{l} \Delta p_t^B = \left(\frac{\partial p_t^B}{\partial p_{t-6}^C} |_{p_*^C, p_*^B} \right) \Delta p_{t-6}^C + \left(\frac{\partial p_t^B}{\partial p_{t-6}^B} |_{p_*^C, p_*^B} \right) \Delta p_{t-6}^B \\ \Delta p_t^C = \left(\frac{\partial p_t^C}{\partial p_{t-3}^C} |_{p_*^C, p_*^B} \right) \Delta p_{t-3}^C + \left(\frac{\partial p_t^C}{\partial p_t^B} |_{p_*^C, p_*^B} \right) \Delta p_t^B \end{array} \right\} \quad (1)$$

Based on a linear approximation of the nonlinear dynamical system in our empirical hypothesis, according to the Hartman Grobman Theorem, the linearization at an equilibrium state is topologically comparable to the behavior of a nonlinear dynamical system around its steady state. In normal circumstances, linear approximation approaches can be used to gain a qualitative knowledge of the dynamics of nonlinear systems away from the steady state [14].

4 Empirical Analysis

Using auto regression techniques to weekly data on mutton farm-gate (inflation-adjusted) prices in China from January 2011 to December 2021, we test hypotheses obtained from our theoretical model. Unit roots are typically found in time-series data. Our unit root analysis reveals that the prices of mutton have unit roots, indicating that a regression model based on price levels is likely to produce false results. As a regression model given by first-differenced prices can be reliably estimated using OLS, unit root tests demonstrate that the first differences of prices are stationary. Three additional observations within the context of our investigation need evaluating the dynamics of mutton pricing in first differences. First-differencing reduces time-series variables' long-term dynamics while enhancing their high-frequency elements [15]. Working with first-differenced data enables us to concentrate on estimating the short-run dynamics of observed prices because our theoretical model's predictions are connected to short-run price changes. Second, first-differencing can reduce nonlinear dependence in time-series variables. Our empirical strategy is based on linear approximations of a hypothesized nonlinear data generating process. Finally, the differentiation operation's analog is first differentiating. It gives estimates that are compatible with the partial derivatives produced from our theoretical model an intuitive interpretation when our econometric model is specified in first differences of prices.

4.1 Model specification and estimation

Relationships resulting from nonlinear dynamical models are typically reformulated as a system of linearized difference equations and placed within a multivariate autoregression framework for empirical research [16]. We add an error process to the linearized difference equations in 15 to transform our theoretical model into a statistical model that describes the data. Here, Bt and Ct stand in for variables—shocks to the broiler and chick markets, respectively—that are not included in our theoretical model. The baseline specification includes covariates (X_j) to reduce the bias caused by omitted variables. A first-differenced quasi-VAR is the equivalent of the system of difference equations. The lag lengths imposed by quasi-VARs are not uniform, and the possibility of specific lags influencing the dynamics of various endogenous variables is permitted by coefficient limitations [17].

$$\left\{ \begin{array}{l} \Delta p_t^B = \beta_1^B \Delta p_{t-6}^C + \beta_2^B \Delta p_{t-6}^B + \beta_j^B X_j + \in_t^B \\ \Delta p_t^C = \beta_1^C \Delta p_{t-3}^C + \beta_2^C \Delta p_t^B + \beta_j^C X_j + \in_t^C \end{array} \right\} \tag{2}$$

The resulting quasi-VAR simply acts as a statistical platform for testing the empirical predictions of our theoretical model using real-world data. The auto regression functions embody equilibrium conditions derived from our theoretical model. Our theoretical approach assures that the accompanying quasi-VAR does not suffer from drawbacks frequently associated with vector auto regression analysis. Formula by formula under common assumptions, OLS estimates of VARs are consistent, and we use OLS to sequentially fit the price equations for broiler and chick meat. Auto correlated residuals in time series regressions are considered using the Newey-West hetero skedasticity and autocorrelation consistent covariance (HAC) estimator.

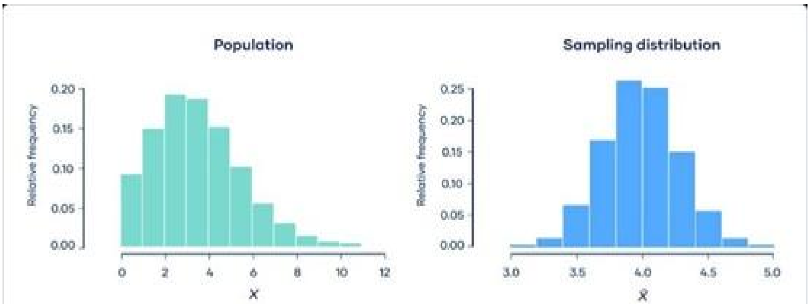
4.2 Explanation of empirical result

Estimates of the baseline specification are given in Table 2. The computed coefficients are statistically significant and in line with what our theoretical model predicts. Estimates from both methods are in line with our initial findings. Our fieldwork results point to seasonal effects driven by the Islamic calendar rather than Gregorian calendar seasonality. For example, during Eid-ul-Adha, mutton demand decreased as households switched to the meat of sacrificed animals. To measure the impact of Eid-ul-Adha on China's mutton supply chain, we use a dummy variable. The baseline standard includes a time trend to take into consideration how technology evolves over time. The estimates in Column II support our first findings. The results of residual diagnostics show that our specifications are quite well defined, and CUSUM tests show that the estimates have remained constant during our investigation.

Table 2. The regressor and mutton price equation.

Regressor	Mutton price equation (ΔpCt)
ΔpCt-3	
ΔpBt	
ΔpBt -6	
ΔpBt-6	-0.120
	(0.060)
Dt	
t	
R^2	0.019
Model diagnostic	
Heteroskedasticity test	1.60
ARCH effects test	0.05
Shapiro-Wilk test	0.50
CUSUM test	0.28
Portmanteau	21.90

Note: Estimates are based on weekly data (350 observations) from January 11th to December 20th. Coefficient estimates are shown in parentheses with row variables with heteroskedasticity and standard errors of autocorrelation consistent covariance (HAC).



*Significance at 10% level.
**Significance at 5% level.
***Significance at 1% level.

Fig. 2. Comparison of Population Distribution and Sampling Distribution: The left histogram represents the relative frequency distribution of a population, while the right histogram shows the sampling distribution of the sample means from the population.

5 Numerical Analysis

In this study, our theoretical model's frugal construction makes it amenable to numerical simulations. In order to assess whether our stylized model is capable of generating the key characteristics of mutton price dynamics in China, we present prices that have been simulated using parameterizations of our theoretical model that are grounded in empirical data and compare the statistical characteristics of the simulated and observed prices. Additionally, we show how feasible model additions greatly enhance the match between real-world and simulated price dynamics by numerical simulations (see Fig. 2).

5.1 Model Parameterization

We parameterize our theoretical model using information from both our fieldwork and the literature on mutton supply networks. In mutton supply chain models, production technologies are often parameterized using aggregate production statistics, industry reports, and farmer surveys. On the basis of this literature, we extrapolate values of sheep farmers fixed-proportion production technology in China using aggregate production statistics from PPA industry reports and government economic surveys, farm level production data, farmer interviews, and the larger body of sheep science literature. The cost function exponents are tuned to reflect control sheds' higher operating costs in the large-scale market compared to open sheds' lower operating costs in small-scale markets. According to customer and retailer interviews, China's demand for food-based commodities is generally inelastic when prices are high and vice versa. Because there is no accurate assessment of the mutton demand in China, we stick to this common-sense idea and use a linear function to describe retailers' mutton demand. Cost and demand function parameters are calibrated to produce nonzero by minimizing the gap between the first moments of observed and simulated prices, cyclical price variations. Aspects of our theoretical model are parameterized using intuitive reasons due to data restrictions. Yet, our model parameterization is plausible and is intimately related to the Chinese mutton supply chain, which gives our numerical study a degree of realism.

6 Conclusion

In this study, we investigate the root reasons of price instability in China's mutton supply chain, and as to empirically test the idea of endogenous price variations. To pinpoint the causes of the observed price variations, descriptive data from fieldwork on the mutton sector in China is used. The result shows that the rapid transformation nature of extreme events such as covid-19 virus caused a lot of issues in the mutton meat industry. All phases of the mutton meat supply chain were negatively impacted by the limits on the export of animals, logistics and closure of slaughterhouses.

These results hold up well under various identifying methods and requirements. Our numerical research shows that prices can accurately recreate the prominent features of price fluctuations in the Chinese mutton supply chain using parameterizations of our theoretical model that are appropriate. A strong argument is made for the existence of endogenous price changes in China's mutton supply chain as a result of the mounting evidence from fieldwork, empirical research, and numerical simulations. In doing so, our paper emphasizes the notion of endogenous pricing instability in agricultural markets' practical applicability.

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