Spatial Price Linkages Between Chinese Regional Beef Markets

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Abstract: This paper investigates the spatial price linkages between Chinese regional beef markets using cointegration methods. Cointegration tests indicate that long-run cointegration relationships exist for many Chinese regional beef markets. However, short-run cointegration relationships are not observed for most regional markets.

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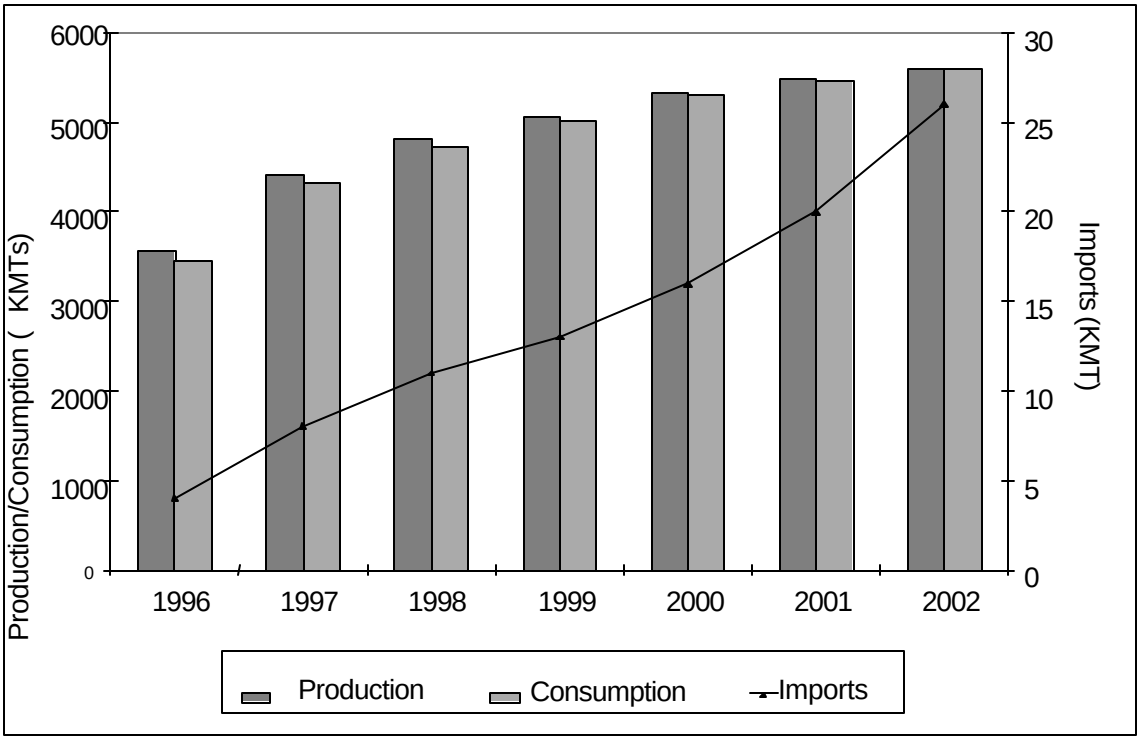
Introduction

China's beef industry has developed rapidly since the beginning of China's reform period in 1978. Over the past two decades, Chinese beef production increased by more than fifteen fold from 269,000 metric tons in 1980 to 5,600,000 metric tons in 2002 (Figure 1). Additionally, China's cattle inventory moved up to the third largest in the world, behind only the United States and Russia. China's beef consumption has also increased progressively over time. The total beef consumption increased from 3,012,000 metric tons in 1980 to 5,581,000 metric tons in 2002 (Figure1). Per capita beef consumption grew from 0.3 kg per year in 1980 to 3.32 kg per year in 1997 and this growth is expected to continue, especially for urban households.

Although China is mainly self-reliant for its overall beef consumption, imports and inter-regional sales play very important roles due to China's regional differences in beef production and consumption (Figure 1). The U.S. takes a leading position in this emerging market, accounting for 53 percent of China's total beef imports (USDA-FAS, 2002). In 2001, U.S. beef exports to China reached $9.4 million. China's regional differences present a growing opportunity for U.S. meat exporters.

In regards to regional differences, per capita beef consumption in northern China is greater than that in the center and southern areas, and beef consumption growth in the relatively affluent coastal regions exceeds that of inland China. However, China's beef production is located in traditional pasture regions in northwest China and intensively

Figure1: Beef Production and Consumption in China in 2001



cropped farming regions in central China (Hu, et al., 1998). In 2002, about 70 percent of beef was produced from eight provinces including Henan, Shangdong, Hebei, Jilin, Anhui, Heilongjiang, Hunan, and Sichuan (see Appended Map 1).

In northern China, beef is supplied from the Hebei province. In eastern China, beef supply comes from the Anhui, Shangdong and Henan provinces. The southern area in China is less suitable for raising cattle and the supply of beef comes from Inner Mongolia, Jilin, Anhui and Henan provinces (see Appended Map 2).

With the development of Chinese beef markets, price differences between regional markets stimulate production and marketing decisions by Chinese producers, agribusinesses and importers of beef products. In 1998, beef prices in Southern China

were reported about 10 percent higher than in Northern China; local supply did not meet local demand (Luo, 1998).

The objective of this paper is to empirically evaluate cointegration and spatial price linkages for Chinese regional beef markets. Cointegration tests are developed and applied to spatial price relationships among thirteen regional beef markets. Insights from these results will provide knowledge about how regional beef market prices interact and thus help Chinese beef producers, distributors and importers as well as U.S. beef exporters to better understand Chinese beef markets.

Price Relationships in Spatial Markets

Spatial price relationships for agricultural products have been widely used to evaluate agricultural market performance. Highly integrated spatial markets usually indicate a highly efficient market mechanism. Monke and Petzel (1984) defined integrated markets as "markets in which prices of differentiated products do not behave independently." For the spatial markets cases, identical products are assumed to be differentiated by locations. And the interdependence between prices at different locations can be used to indicate the degree of market integration.

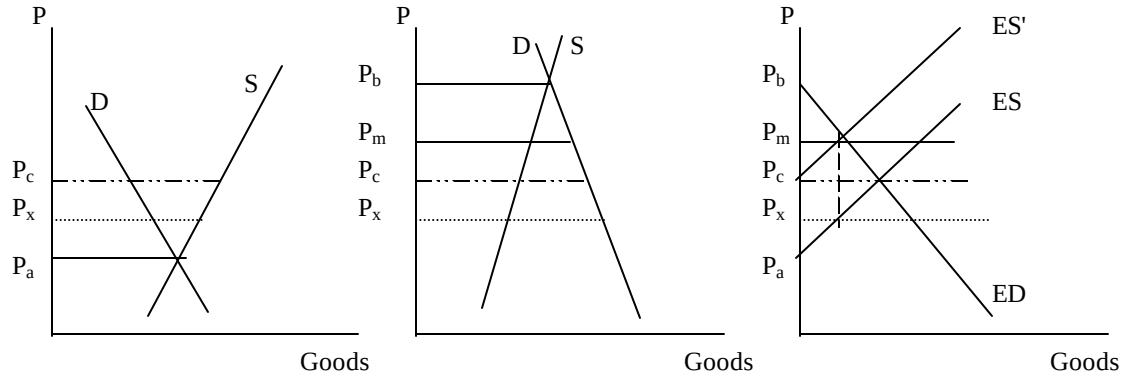
In the long run, commodity arbitrage or collusive basing-point pricing will ensure a unique equilibrium relationship in which deviations from regional price parity are forced to zero. Such an equilibrium does not necessarily require that deviations from equilibrium should always be zero or even serially uncorrelated. Delivery lags between spatial markets and other impediments to regional trade and arbitrage activities might result in the short-run persistence of deviations from the steady-state equilibrium.

Similarly, incomplete basing-point pricing behavior may also result in short-run deviations from equilibrium conditions (Faminow and Benson, 1990).

Two generally accepted principles about regional price differences (Tomek and Robinson, 1981) are (a) price differences between any two regions (or markets) that trade with each other will just equal transfer costs; (b) price differences between any two regions (or markets) that do not engage in trade with each other will be less than or equal to transfer costs. Takayama and Judge (1971) provide the necessary theoretical justification for these principles by giving certain explicit assumptions. In particular, all transactions within a region are assumed to occur at a point; that is, no intraregional transportation costs apply (effectively, all buyers and sellers are located at a single point).

Under the assumption of perfect competition, trade relationship and market cointegration between two regional markets can be illustrated by Figure 2. P_a and P_b are the equilibrium prices for the export region and the import region, respectively. ES and ED are excess supply curve and excess demand curve. Before trade, it is clear that the equilibrium price in export market P_a is much lower than that in import market P_b. After trade, the equilibrium price for these two regional markets will arrive at P_c without considering the transfer costs. When taking the transfer costs into account, the excess supply curve will shift left from ES to ES'. The equilibrium price in the import regional market will increase from P_c to P_m and the equilibrium price in the export regional market will come down from P_c to P_x. And the difference between P_m and P_x is the transfer costs. If that is the case, the two regional markets are said to be cointegrated.

Figure 2: Regional Market Trade Equilibrium



The framework of cointegration tests for evaluating spatial market linkages have been developed by Granger (1986), Engle and Granger (1987), and Engle and Yoo (1990).

In essence, the general cointegration procedures appeal to the fact that deviations from long-run equilibrium conditions for two economic variables, which are nonstationary by themselves, should be stationary. The intuition behind this is that economic forces should prohibit persistent long-run deviations from equilibrium conditions, although significant short-run deviations may be observed. An important implication from this is that, even though individual economic variables such as prices may wander extensively, certain pairs of such variables should not diverge from one another in the long run. Spatial market integration will require that deviations from economic equilibrium conditions have a stable mean of zero. In terms of cointegration, this condition implies that two spatially separated markets are spatially linked and interdependent if regional prices can be used to form a cointegrating regression representative of a spatial price parity equilibrium condition.

Cointegration Tests of Spatial Linkages Among Chinese Beef Markets

Conventional tests for spatial market integration is based upon the law of one price. The strong version of this law for efficient markets states that the price in one market is expected to be the same as that in an alternative market. That is:

$$E(p_t^i \mid I_{t-1}) = p_t^j \quad (1)$$

where p_t^i and p_t^j represent logarithmic commodity prices in two alternative regional markets and I_{t-1} represents all of the information available to the price decision makers at time t-1. For example, I_{t-1} would include all lagged values of both p_t^i and p_t^j, as well as other relevant information. We may reformulate equation (1) as:

$$p_t^i = p_t^j + z_t \quad (2)$$

where $E(z_t \mid I_{t-1}) = E(z_t \mid z_{t-1}, z_{t-2}, \ldots) = 0$. In reality, there may be a number of reasons against holding the basic relationship in (2) in the short-run. For example, the short run model in (2) would be rewritten as:

$$\Delta p_t^i = \alpha_0 + \beta \Delta p_t^j + u_t \quad (3)$$

where the residual error term u_t represents proportional deviations from price parity.

Before applying above empirical cointegration tests, the Augmented Dickey Fuller (ADF) method is utilized to test whether or not the logarithmic commodity price series p_t^i and p_t^j are stationary variables. Most economic variables such as price level that exhibit strong trends are nonstationary. If a stationary process can be produced by taking a first difference on a nonstationary variable, this variable is said to be integrated

of order one, denoted I(1). I(0) denotes a stationary variable. Obviously, an I(0) version of (2) would hold in the short-run only if $\alpha_0 = 0$ and $\beta = 1$.

Specifically, we can perform ADF regressions as:

$$\Delta p_t^i = \alpha_1 + \rho p_{t-1}^i + \sum_{k=1}^{r} \gamma_k \Delta p_{t-k}^i + e_t \qquad (4)$$

Then, we can do unit root tests on the ρ parameter to determine whether or not each series is more closely identified as being I(1) or I(0) process.

The standard tabulated critical values for the ADF tests are used. If the ADF unit root test values are less than those critical values in absolute terms, we fail to reject the null hypothesis that H_0: $\rho = 0$ (i.e., we fail to reject the hypothesis of a unit root). In such case, we need to proceed to examine whether or not the relationship represented in (2) holds in the long-run.

By estimating ADF regressions on $Z_t = p_t^i - p_t^j$ and testing in the usual manner to see whether or not Z_t is associated with a unit root, the spatial price linkages between a pair of regional markets can be then evaluated.

By adding additional lags of both variables to the model, the short-run relationship among regional markets can be assessed. Specifically, we might have, in lieu of (3), a regression equation of the following form for each pair of price series:

$$\Delta p_t^i = \alpha_0 + \alpha_1 \Delta p_{t-1}^i + \gamma_1 \Delta p_t^j + u_t \qquad (5)$$

Of course, additional lags of both variables might be appropriately included in (5). Because each of the series Δp_t^i and Δp_t^j are I(0), the estimates of the parameters in (5) will be consistent and asymptotically normal.

Furthermore, we can have the error correction model (ECM) by incorporating an additional I(0) variable into the regression in (5). Specifically, we might have:

$$\Delta p_t^i = \alpha_0 + \alpha_1 \Delta p_{t-1}^i + \gamma_1 \Delta p_t^j + \delta (p_{t-1}^i - p_{t-1}^j) + u_t \quad (6)$$

The term $\delta (p_{t-1}^i - p_{t-1}^j)$ is called the error correction term.

According to the Engle-Granger procedure, the intercept $\hat{\alpha}_0$ can also be considered in model (6) by such form:

$$\Delta p_t^i = \alpha_0 + \alpha_1 \Delta p_{t-1}^i + \gamma_1 \Delta p_t^j + \delta (p_{t-1}^i - \hat{\alpha}_0 - p_{t-1}^j) + u_t \quad (7)$$

where presumably the intercept $\hat{\alpha}_0$ has been estimated by an OLS cointegrating regression in the first step. This two-step procedure yields consistent and asymptotically estimators of all of the parameters in (7).

Data Description

Monthly beef prices were collected for 13 Chinese regional markets in provincial level from April 1998 through October 2002, yielding a total of 55 monthly observations for each regional market. The data is published by China's Ministry of Agriculture every month (China's Ministry of Agriculture). Regional markets selected in this study cover 13 provinces, including the eight main beef producing provinces--Henan, Shangdong, Hebei, Jilin, Anhui, Heilongjiang, Hunan, and Sichuan--and five other provinces--Jiangsu, Beijing, Inner Mongolia, Guangdong, and Guizhou. These markets are geographically dispersed with varying degrees of interregional exchange. There are a small number of missing observations for some regional markets which are proxied by the moving average value.

Empirical Results of Cointegration Tests

1. Stationarity of Price Series

In estimation, we take the natural logarithms of all prices and multiply by 100 (i.e., first differences will represent percentage changes). To test for unit roots of the variables, ADF tests are conducted without using a trend (initial investigations indicated that the prices were not necessarily trending during the sample period). The ADF tests results for the stationarity of price series are reported in Table 1.

Table 1: Beef Price Series Stationarity ADF Tests: I(1)

Regional Market	ADF Test Value	Regional Market	ADF Test Value
Henan	-0.94	Sichuan	-0.64
Shangdong	0.06	Jiangsu	-1.92
Hebei	-0.19	Beijing	-1.93
Jilin	-0.87	Inner Mongolia	-0.62
Anhui	-1.94	Guangdong	-3.03
Heilongjiang	0.06	Guizhou	-0.76
Hunan	-1.15	5% Critical Value	-2.86

The ADF critical value is –2.86. We therefore fail to reject the null hypothesis of a unit root at the 5 percent level of statistical significance in each case except for Guangdong's price. We can conclude that there is evidence that each of the price series is I(1), which implies that there is a trend underlying these regional beef market prices, and that first differencing will likely render them I(0).

2. Long-run Cointegration Tests

The long-run cointegration test results are reported in table 2. Again, the critical value at the 5 percent level is -2.86. If the ADF test value is greater than the critical value, we can reject the null hypothesis that there is no long-run cointegration

relationship at the 5 percent level and conclude that the pair of regional markets is cointegrated. Table 2 shows that there are valid long-run cointegration relationships for many pairs of regional markets. Anhui and Guangdong play the central role in these cointegration relationships.

- Anhui is cointegrated with Henan, Shangdong, Hebei, Jiling, Heilongjiang, Sichuan and Guangdong.
- Guangdong is cointegrated with Shangdong, Hebei, Jilin, Anhui, Heilongjiang, Hunan, Beijing and Inner Mongolia.

Currently, China's poor transportation infrastructure constrains domestic beef trade among regional markets. Anhui is one of the main beef production provinces in central China. This central location gives Anhui a geographic advantage in selling beef products to other Chinese regions. This may be the reason why Anhui's beef market is cointegrated with so many regional markets.

Guangdong is a large consumption area and the beef re-export area to Hong Kong. Price mechanism plays a very active role in this market. This may be the reason why the Guangdong beef market is cointegrated with so many regional markets.

In contrast, Beijing is not cointegrated with other beef markets except for Guangdong even though it is also a large consumption area like Guangdong. This may be the result of government policy interventions. Because Beijing is the capital of China, the government tends to intervene in this market to ensure stable beef prices, which makes Beijing's beef price seem less related with prices in other markets.

3. Short-run Cointegration Tests

To account for short-run price dynamics, we estimate the error correction models for each pair of regional markets. The specifications investigated in this study are of the form:

$$\Delta p_t^i = \alpha_0 + \alpha_1 \Delta p_{t-1}^i + \alpha_2 \Delta p_{t-2}^i + \gamma_1 \Delta p_t^j + \gamma_2 \Delta p_{t-1}^j + \gamma_3 \Delta p_{t-2}^j$$

$$+\delta (p_{t-1}^i - \hat{\alpha}_0 - p_{t-1}^j) + u_t \qquad (8)$$

That is, two lags of the first differences of the pair of the regional market beef prices are used to explain the price changes in the short run.

By conducting an F-test on the model (8), we can conclude if there exists a short-run cointegration relationship for the pair of regional beef markets. If we can reject the null hypothesis that H_0: $\alpha_1 = \alpha_2 = \gamma_1 = \gamma_2 = \gamma_3 = 0$ and $\delta = 1$, it can be concluded that there is no short run cointegration relationship for the pair of regional beef markets.

For a dynamically stable model, δ is suppose to be negative in each case. A value of δ close to -1 would suggest that adjustments toward the long-run efficient market hypothesis condition occur rapidly, while a value close to zero would suggest that adjustments to the long-run occur rather slowly.

The short run cointegration test results are reported in Table 3. The results indicate that most of the regional beef markets are not cointegrated in the short run except for Jiang with Anhui, Heilongjiang, Huan, and Beijing with Heilongjiang, Hunan, Sichuan, and Guangdong with Heilongjiang, Sichuan, Guizhou, and Inner Mongolia with Hunan, Sichuan. This may result from following possible reasons:

(1) Poor transportation infrastructure. This is the main reason for low short-run cointegration. Limited transportation capacity makes it impossible for a local market to reflect the price changes in other regional markets.

(2) Aggregation of selected price series data. The data used in this study are monthly price series, which may not reflect the short run price changes, especially for the pairs of markets with short distance. However, this is not the main reason. Because of the poor transportation infrastructure, price information availability and some government intervention, China's beef trade across regions will not be realized within a very short period.

(3) Government intervention. To protect its local beef production, some local governments tend to pose constraints on beef imports from other provinces so that beef trade across provinces, even across cities, cannot be realized. Therefore, price changes in other regional beef markets cannot be reflected in the local markets.

(4) The reason for the short-run cointegration for the pair of Jiangsu-Anhui, Jiangsu-Hunan and Beijing-Heilongjiang may be the short distance, convenient transportation and less government intervention. The reason for other market pairs with short-run cointegration may be due to the special position of Beijing and Guangdong in the beef market. Disturbance from missing values may also contribute to estimation of short-run cointegration relationships between some markets.

Concluding Remarks

With the development of the Chinese beef industry, regional beef markets have developed closer relationships. Price differences between regional beef markets stimulate production and marketing decisions by Chinese producers, agribusinesses and importers

of beef products. Empirical results show that there exist long-run cointegration relationships for many regional beef markets. However, short-run cointegration relationships are not observed for most regional markets. Such relationship implies that Chinese agricultural markets begin to play a role in coordinating regional inequality in beef products supply and demand. However, its effect is limited. For U.S. beef exporters, it means that their products will possess great competitiveness in Chinese market if they can build up an efficient marketing system. Unobserved short-run cointegration relationship indicates that it is important and necessary for U.S. beef exporters to take a markets segmentation strategy.

Table 2: Long-run Cointegration Tests (ADF Test Values)

	Shangdong	Hebei	Jilin	Anhui	Heilongjiang	Hunan	Sichuan	Jiangsu	Beijing	Inner Mongolia	Guangdong	Guizhou
Henan	-2.48	-2.59	-2.20	-3.51*	-1.77	-2.78	-2.59	-1.07	-1.71	-1.92	-2.45	-1.83
Shangdong		-2.25	-2.73	-4.24*	-2.50	-2.83	-2.78	-1.03	-0.66	-3.50*	-3.05*	-2.50
Hebei			-2.48	-4.78*	-1.53	-3.46*	-2.27	-1.42	-2.39	-2.18	-3.34*	-1.62
Jilin				-3.07*	-3.17*	-2.52	-2.62	-1.16	-1.15	-2.93	-3.12*	-2.84
Anhui					-3.30*	-2.78	-3.25*	-0.71	-2.47	-2.20	-3.15*	-2.16
Heilongjiang						-2.28	-2.44	-1.24	-0.86	-3.23*	-3.10*	-1.66
Hunan							-1.97	-0.88	-2.04	-1.26	-2.94*	-1.82
Sichuan								-0.40	-1.80	-1.88	-2.22	-1.98
Jiangsu									-2.22	-0.73	-1.61	-0.62
Beijing										-1.35	-2.92*	-1.14
Inner Mongolia											-3.29*	-1.79
Guangdong												-1.56

Note: * indicates that there is long-run cointegrated relationship for the pair of regional markets.

Table 3: Short-run Cointegration Tests

	Shangdong	Hebei	Jilin	Anhui	Heilongjiang	Hunan	Sichuan	Jiangsu	Beijing	Inner Mongolia	Guangdong	Guizhou
Henan	6.56[a] -0.43[**b]	5.03 -0.32[*]	3.38 -0.16	2.93 -0.00	3.97 -0.23[*]	3.02 -0.05	4.00 -0.25[*]	6.34 0.02	5.80 -0.11	4.08 -0.07	4.15 -0.08	5.10 -0.19[**]
Shangdong		11.14 -0.30[*]	8.52 -0.09	9.21 0.07	12.63 -0.51[**]	8.38 0.00	8.76 -0.15	8.89 0.08	10.30 0.04	8.99 -0.13	8.50 -0.06	8.62 -0.06
Hebei			4.72 -0.09	2.79 0.00	6.43 -0.35[**]	2.43 -0.08	3.10 -0.07	2.59 0.02	2.74 -0.00	5.70 -0.16	3.44 -0.13	2.83 -0.08
Jilin				4.45 -0.10	6.33 -0.50[**]	5.03 -0.25[**]	6.33 -0.31[**]	4.45 -0.07	5.53 -0.19	12.27 -0.25[*]	5.19 -0.18	6.35 -0.26[**]
Anhui					3.88 -0.45[**]	2.59 -0.47[*]	5.62 -0.75[**]	1.43[*] -0.07	2.53 -0.29[**]	3.22 -0.32[*]	2.79 -0.34[**]	2.46 -0.26[*]
Heilongjiang						2.50 0.00	2.20 -0.10	1.55[*] 0.00	1.77[*] -0.00	4.42 -0.34[**]	1.65[*] 0.02	2.05 -0.06
Hunan							4.44 -0.58[**]	0.58[*] -0.06	1.30[*] -0.25[**]	2.09[*] -0.35[**]	2.57 -0.31[**]	1.05 -0.17
Sichuan								3.09 0.12[**]	1.47[*] -0.04	1.82[*] -0.07	1.53[*] -0.08	2.05 -0.12
Jiangsu									5.65 0.47[**]	2.77 -0.12	3.12 -0.20[*]	3.83 -0.29[**]
Beijing										2.74[**] -0.12	2.21 -0.30	3.47 -0.16[**]
Inner Mongolia											5.34 -0.14	5.77 -0.14
Guangdong												0.79[*] -0.10

Note: a The first value of cells in the table is F-test value. * indicates there is short-run cointegration relationship.
b The second value of cells in the table is the value of d. * indicates d is significantly different from zero at 10 percent level and ** indicates d is significantly different from zero at 5 percent level.

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Appended Map 1: Selected Chinese Regional Beef Markets

Note: Selected markets are marked in green and pink.

Appended Map 2: Chinese Regional Beef Supply