Reassessing China's Livestock Statistics: An Analysis of Discrepancies and the Creation of New Data Series*

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I. Introduction

Given the importance and rapid pace of change of China's livestock sector, there is high demand for good information about past, current, and future trends, the information that is needed to facilitate decision making in the livestock and food sectors. Because of the public goods nature of many investments and because of the political importance of agriculture, leaders in all countries have typically demanded that statistics be collected on agricultural inputs and outputs.[1] Government officials need good information for planning, creating sectoral policies, and allocating budgets. Producers, both large and small, need timely information on which they can base their investments in projects that range in size from large commercial operations to backyard pens. Those charged with negotiating and managing China's trade agreements, including the nation's top leaders, also need to have accurate predictions about future supply, demand, and trade. More important, domestic livestock production directly determines feed demand, which in turn affects grain imports, in particular, feed grain import.[2]

Unfortunately, China does not have a good record in the generation of reliable and consistent data on the demand and supply of livestock products.[3] An examination of livestock data derived from national statistical sources reveals that the discrepancy between published demand and supply series has become larger over the past 15 years. Although China's National Statistical Bureau (CNSB) already has implicitly admitted that its data series are flawed

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by making substantive revisions after the late 1990s, its changes still have not changed the growth rates of the nation's livestock production. By 1999, China's production series reached a level two to three times as high as its consumption series. In contrast, national statistics show that the consumption of pork did not rise during the 1990s, even though per capita income in real terms during this time period rose by 6% annually. Recognizing weaknesses in the national government's official statistics, several statistical users have spent time adjusting and revising livestock databases and rerunning baseline projections on China's grain production, demand, and trade.[4] One of the tasks of China's 1997 census of agriculture was to assess and adjust livestock production data.[5] Despite this effort, however, the lack of consistent data almost certainly is affecting the quality of research. For example, F. Zhong suggests that projections made by previous studies on food demand and supply could be subject to serious bias because of faulty data on livestock and should be reexamined.[6] If so, the policy recommendations that have been derived from the previous studies also may have to be reexamined.

The overall goal of this article is to understand the discrepancies in China's official livestock production and consumption data, to provide two adjusted series for production and consumption, and to show how these new series are internally consistent. We also will examine the implications of using our adjusted data series to assess China's livestock performance and the impact of exogenous policy shocks on the economy. We will show that the nature of the contours of meat production and consumption data significantly affect the results of supply, demand, and trade analyses, especially as they relate to predicted outcomes in the livestock economy and agricultural trade.

To meet these goals, our article is organized as follows. In the next section, after discussing criteria that can be used to assess the consistency and quality of livestock data, we show the discrepancies between China's livestock demand and supply and demonstrate that these two series are internally inconsistent. In Section III, we introduce the data that are used for our adjustments. In Sections IV and V, we discuss at length the assumptions and strategy that we use to create our adjusted data series and present our adjusted demand and supply series. We will use a series of statistical tests to track the magnitude of the discrepancies and the effectiveness of the adjusted series in narrowing the gap between supply and demand. In the final sections, we assess the quality of the adjusted series to see the implication for China's cereal trade using the adjusted series versus that of other series and draw our final conclusions.

II. Livestock Demand and Supply Discrepancies

In order to assess the validity of any given set of livestock statistics, several criteria need to be met. First, after adjusting for trade and storage, domestic supply must equal demand. Second, the production of meat must be consistent with feed statistics. Third, the numbers must be consistent with observed trends in the economy. In this section, we show that China's official published livestock demand and supply data fail to meet these criteria.

Supply Does Not Equal Demand

If China's official statistics on livestock were correct, the supply of livestock products during the past 2 decades would have increased at a rate almost unparalleled in history (table 1). According to production statistics from China statistical yearbooks (the official publications of major agricultural statistics, managed by a division of CNSB), aggregate pork supply rose by 2.4 times, from 11.34 million metric tons in 1980 to 38.91 million metric tons in 1999 (col. 1). Other livestock products grew even faster. For example, poultry supply increased by 10.9 times, from 0.94 million metric tons in 1980 to 11.16 million metric tons in 1999 (col. 4). Egg, beef, and mutton supplies increased by at least five times (cols. 7, 10, 13).

As supply grew, China's statistics show that the demand for livestock products also increased (table 1, cols. 2, 5, 8, 11, 14). According to CNSB's officially sanctioned urban and rural Household Income and Expenditure Surveys (urban HIES and rural HIES), total pork consumption doubled from 10.47 million metric tons in 1980 to 21.94 million metric tons in 1999. Likewise, consumption of other animal products grew. For example, poultry consumption became 5.3 times greater, while eggs, beef, and mutton consumption all increased by at least two times.

Comparing initial levels of livestock demand and supply in the early 1980s (which were nearly equal through 1987) and analyzing the trends for the past 15 years (which were sharply different) illustrate that CNSB's livestock demand and supply data are inconsistent. The rising ratio of supply to demand throughout the entire period demonstrates the extent to which supply figures are growing faster than those of demand (table 1). For example, for most of the 1980s (1980–87), the ratio of pork supply to demand averaged 0.97, nearly 1.00 (col. 3). China's pork statistics during the time met the criterion that supply equal demand. Between 1988 and 1999, however, the ratio increased monotonically from 1.15 to 1.77. China's reported pork supply exceeded the reported demand by 77% in 1999. The ratios of other livestock commodities increased even faster (cols. 6, 9, 12, 15).

Statistical tests of the rising gap between demand and supply provide further confirmation of the observation that China's supply figures are growing faster than those of demand. Our statistical tests are derived from the following equations:

$$R_{it} = \beta_0 + \beta_1 T_{t \leq 1987} + \beta_2 T_{t > 1987} + u_i, \tag{1}$$

where R_{it} is the ratio of supply to demand over time, $T_{\leq 1987}$ is a time trend variable for the period 1980–87, and $T_{t>1987}$ is a time trend variable for the period 1988–99; and

$$R_{it} = \alpha_0 + \alpha_1 T_t + \varepsilon_i, \tag{2}$$

where T_t is either the first time period (1980–87) or the second one (1988–99). In equation (1), the coefficient on the early time trend variable, β_1, would demonstrate that supply equals demand between 1980 and 1987 if $\beta_1 = 0$. It

TABLE 1

Comparisons between Aggregate Livestock Supply and Demand Statistical Series in China, 1980–99 (Million Metric Tons)

	Pork			Poultry			Eggs			Beef			Mutton		
Year	Demand (1)	Supply (2)	Ratio (3)	Demand (4)	Supply (5)	Ratio (6)	Demand (7)	Supply (8)	Ratio (9)	Demand (10)	Supply (11)	Ratio (12)	Demand (13)	Supply (14)	Ratio (15)
1980	10.47	11.34	1.08	.88	.94	1.07	2.13	2.57	1.20	.28	.27	.97	.42	.45	1.05
1981	11.84	11.88	1.00	1.02	1.03	1.00	2.24	2.69	1.20	.30	.24	.82	.46	.48	1.03
1982	13.23	12.72	.96	1.25	1.18	.94	2.31	2.81	1.22	.37	.27	.72	.50	.52	1.04
1983	14.63	13.16	.90	1.35	1.30	.96	2.69	3.32	1.23	.41	.31	.77	.52	.55	1.04
1984	16.07	14.45	.90	1.52	1.44	.95	3.15	4.32	1.37	.53	.37	.70	.57	.59	1.03
1985	16.73	16.55	.99	1.77	1.60	.90	3.57	5.35	1.50	.66	.47	.71	.63	.59	.93
1986	18.76	17.96	.96	1.95	1.88	.96	3.63	5.55	1.53	.74	.59	.79	.66	.62	.94
1987	18.40	18.35	1.00	2.03	2.19	1.08	4.05	5.90	1.46	.87	.79	.91	.69	.72	1.04
1988	17.56	20.18	1.15	2.27	2.74	1.21	4.38	6.96	1.59	.98	.96	.98	.71	.80	1.13
1989	18.13	21.23	1.17	2.45	2.82	1.15	4.60	7.20	1.57	1.07	1.07	1.00	.77	.96	1.25
1990	18.91	22.81	1.21	2.68	3.23	1.21	4.78	7.95	1.66	1.19	1.26	1.06	.85	1.07	1.26
1991	20.20	24.52	1.21	2.82	3.95	1.40	5.10	9.22	1.81	1.33	1.54	1.16	.92	1.18	1.29
1992	19.69	26.35	1.34	3.18	4.54	1.43	5.51	10.20	1.85	1.39	1.80	1.30	.90	1.25	1.39
1993	19.95	28.54	1.43	3.41	5.74	1.68	5.44	11.80	2.17	1.46	2.34	1.60	.90	1.38	1.53
1994	19.49	32.05	1.64	3.64	7.55	2.07	5.94	14.79	2.49	1.41	3.27	2.32	.94	1.61	1.72
1995	20.03	36.48	1.82	3.95	9.35	2.36	6.22	16.77	2.69	1.44	4.15	2.88	.96	2.02	2.09
1996	21.81	31.58	1.45	4.28	8.96	2.09	6.40	19.65	3.07	1.52	3.56	2.35	1.08	1.81	1.67
1997	20.54	35.96	1.75	4.92	9.55	1.94	7.34	18.97	2.58	1.82	4.41	2.42	1.23	2.10	1.71
1998	21.50	38.84	1.81	5.02	10.23	2.04	7.71	20.21	2.62	1.76	4.80	2.73	1.23	2.35	1.90
1999	21.94	38.91	1.77	5.58	11.16	2.00	8.02	21.35	2.66	1.86	5.05	2.71	1.19	2.51	2.12

Sources.—Production statistics come from China statistical yearbooks, 1981–2000. Consumption estimates come from CNSB's rural and urban HIES, 1981–2000. Calculations are detailed in Hengyun Ma, Jikun Huang, and Scott Rozelle, "Reassessing China's Livestock Statistics: Analyzing the Discrepancies and Creating New Data Series," working paper (Center for Chinese Agricultural Policy, Chinese Academy of Sciences, and Department of Agricultural and Resource Economics, University of California, Davis, 2002), apps. 1 (pork, poultry), 7 (eggs), 10 (beef), and 11 (mutton).

Note.—Figures report carcass weight. Retail weight figures (original units for consumption data) are converted to carcass weight (original units for production data) using standard conversion coefficients (0.77 for pork, 1.0 for poultry, 0.74 for beef, and 0.89 for mutton; see Frank Fuller, Dermot Hayes, and Darnell Smith, "Reconciling Chinese Meat Production and Consumption Data," *Economic Development and Cultural Change* 49 [2000]: 23–43).

TABLE 2

CONSISTENCY TESTS FOR THE REPORTED LIVESTOCK SUPPLY AND DEMAND SERIES, 1980–99

	DEPENDENT VARIABLE, R_{it} = Supply/Demand				
INDEPENDENT VARIABLE	Pork	Poultry	Eggs	Beef	Mutton
Tests for structural change:					
$T_{t\leq 1987}$	.02	.03	.08***	.08	.02
	(.98)	(1.12)	(3.06)	(1.55)	(1.08)
$T_{t>1987}$	.04***	.07***	.09***	.11***	.05***
	(7.23)	(6.44)	(10.01)	(6.20)	(6.70)
Adjusted R^2	.86	.70	.89	.77	.82
Tests for convergence of supply/demand ratio to one:[a]					
Before 1987:					
$T_{t\leq 1987}$	−.01	−.00	.06***	−.01	−.01
	(.86)	(.29)	(6.01)	(.50)	(1.49)
Intercept	1.01***	1.00***	1.09***	.83***	1.06***
	(21.64)	(18.80)	(23.44)	(10.35)	(33.44)
F-statistic (test: Intercept = 1)	.04	.00	3.97	4.21**	2.84
After 1987:					
$T_{t>1987}$	.07***	.10***	.12***	.19***	.08***
	(6.89)	(5.23)	(6.38)	(7.67)	(6.78)
Intercept	.51**	.12	.53*	−.94*	.37
	(3.48)	(.96)	(1.90)	(2.49)	(1.98)
F-statistic (test: Intercept = 1)	11.61***	6.58**	2.72	26.42***	11.67***

NOTE.—For the tests of structural change (rows 1–3), the equation regressing a time trend from two periods on the supply/demand ratio is run with an intercept; parameters are not shown. Two separate within-period equations are used to test for convergence of supply/demand ratio to one (rows 4–6, 7–9). Figures in parentheses are *t*-statistics.

[a] To test the null hypothesis that the supply/demand ratio is equivalent to one, we test for the significance of the intercept. If *F*-statistics (rows 6, 9) are greater than 4, we reject the null hypothesis.

* Significant at 10% level.

** Significant at 5% level.

*** Significant at 1% level.

would be greater than zero if the ratios were rising and the growth rate of supply was growing faster than demand during the early part of the study period. If the ratios were accelerating during the later time period, 1988–99, the coefficient β_2 on the second time trend variable $T_{t>1987}$ would be positive and significantly different from zero (and significantly different from $T_{\leq 1987}$). In equation (2), if α_1 equals zero and α_0 equals one, then the ratios of supply to demand series converge to one (which means that supply and demand series are equal).

Table 2 clearly displays that China has a problem with its statistical reporting system and that the problem appeared in the late 1980s and 1990s. In the case of all livestock products (except eggs), the ratios between demand and supply remained constant between 1980 and 1987 (the coefficients of $T_{\leq 1987}$ are not significantly different from zero; row 1). Meanwhile, in all cases between 1988 and 1999, the ratios rose significantly (the coefficients of

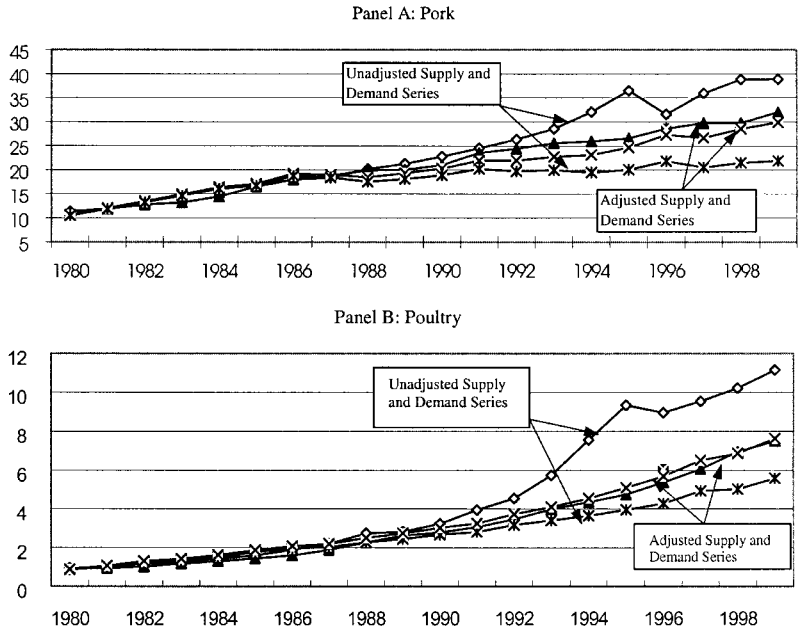

FIG. 1.—Comparison of pork and poultry supply (production) and demand (consumption) statistical series before and after adjustments, 1980–99 (million metric tons). Unadjusted pork and poultry supply and demand statistical series come from table 1, cols. 1–2 and 4–5, respectively. The adjusted pork and poultry supply and demand series come from table 5, cols. 3, 5, and table 6, cols. 3, 5, respectively.

$T_{t>1987}$ differ significantly from zero; row 2). The F-tests demonstrate that in all cases (except beef), the ratios between 1980 and 1987 statistically converge to one (row 6), while the ratios (except eggs) between 1988 and 1999 do not (row 9).

A graphical presentation also clearly illustrates the growing gap between supply and demand statistical series (fig. 1). Although the two unadjusted series for pork (the uppermost and lowermost graph lines on the figure) trend together in the early and mid-1980s, supply begins to rise much faster than demand after the late 1980s (panel A). The same rising gap appears for poultry (panel B).

The Failure to Meet Other Criteria

China's official livestock figures also fail to pass two other consistency tests. First, official demand and supply data clearly fail to provide consistent series of livestock output and feed availability data. To show this, we generated approximate feed consumption figures by aggregating the feed consumption numbers that are implied by various livestock output series.[7] Next, China's supply of feed is assumed to come from its domestic sources and trade.[8] Based on these figures (not shown), we see that although the feed supply and con-

sumption data are nearly the same until the late 1980s, the gap widens noticeably through the 1990s. By 1999, feed demand implied by China's national statistical series is 32.6% higher than feed supply. Since most analysts believe that China's production side statistics for grain are relatively reliable, it would appear from this exercise that livestock production statistics are becoming increasingly overstated in the 1990s.[9]

Second, when examining both demand and supply figures, we find that neither reflects the reality of what is being observed in the field. Official output statistics say that from 1990 to 1999 the livestock production rose by 117%, which would mean that herd size would have almost had to double, on average, in every part of the nation. While certainly there has been a healthy expansion of hog production in some areas, at the same time, farmers in many other areas have reduced their herd size or stopped raising animals altogether.[10] On the demand side, although people may not be eating more pork at home, there has been a veritable explosion of restaurants in China's cities and in many rural areas. The per capita retail value of the catering industry rose more than 130% from 1991 to 1998, and, as anyone who is familiar with China knows, when one goes into a restaurant, meat dishes almost always fill the table.[11] Moreover, the population of migrants has also risen rapidly. In terms of its impact on consumption, J. Huang and H. Bouis show that, holding income and prices constant, one salient characteristic of the demand behavior of migrants is that they invariably consume larger quantities of livestock products.[12] The surge in consumption that must have come with the increased presence of migrants in urban areas (more than 100 million in 2000), however, seems to appear in neither rural nor urban published consumption statistics. In summary, with all of this new consumption occurring, it seems doubtful that consumption could be flat.

III. Data

Although our new data series will ultimately differ from the current ones, we still assume there is valid information in the existing series and build on these series throughout our analysis. The current production series are based primarily on year-end reports produced annually by village accountants who use a variety of means to estimate the slaughter rates of livestock in their villages. Village officials send these reports to the township where they are aggregated. In the most typical case, the township statistical officer reviews the production reports before adding them up to form the township's estimated production figure. This procedure is repeated at each successive level of government (i.e., county, prefecture, and province) before turning into a national set of livestock production data. Although this procedure provides an annual census of livestock activities, the main weaknesses of the data collection system are that there are no absolute criteria upon which local accountants based their estimates and that there are no procedures in place to verify the accuracy of the year-end reports at any level to ensure that they have not been altered by local officials. Without rigorous data collection procedures and verification

processes, observers believe that the current system has allowed local officials to artificially inflate production figures as a way of helping them meet income and food production growth targets.[13]

The current consumption series is based on data that are collected on a more conventional basis by CNSB. Each year, CNSB's personnel across the nation randomly choose more than 40,000 urban and 65,000 rural households to take part in HIES. Using year-round diary methods, households record the quantities and expenditures of the livestock products, in addition to all other consumption goods, that they consume. They also record the expenditures that each household member makes on food consumed out of the home. National aggregate consumption series for each commodity (e.g., pork, chicken), however, are estimated only from that part of the data that households have recorded on the quantities of the livestock products that they directly consumed at home. Such figures do not include the part of consumption that is consumed during meals out of the home. We also believe that respondents systematically miss some of the livestock products that they consume as part of processed foods. Although China's statistical reporting system has made great progress for the past 10 years and the HIES is thought to be fairly reliable, our main concern here is whether or not the categories on which the national aggregates are created are complete.[14]

The sample size and the coverage of China's surveys are changing over time in a number of ways, all of which might have some effect on data quality.[15] For example, the sample size for the rural household survey before 1985 was less than half of its current size (and of that during the 1990s). Especially when the sample was first being formulated, there was some concern that it might not be representative and that it favored richer areas. Moreover, since data are collected primarily on the basis of self-recorded diaries, there is also the possibility even after 1985 (when the locality selection is thought to have become less biased) that the sample is somewhat biased in favor of richer households. On the urban side, the urban HIES initially covered only those households who lived in cities, excluding those who lived in county-level towns. If richer rural or urban households have both higher production and consumption of livestock products, these features of the data system would lead to a sample bias, most likely overestimating production and consumption before 1985.

In order to adjust the current official livestock demand and supply series, we will rely on several different sets of data (table 3). Our adjustments depend heavily on information that is included in China's urban and rural HIES data sets but that is currently not used in creating the national production and consumption series. For example, on the urban side (urban HIES, row 1), since 1991, urban respondents recorded in their expenditure diaries their out-of-home food expenditures. We will use this information in conjunction with other information from our own surveys to make adjustments to our urban animal product consumption series.

Two additional pieces of information are used from the HIES conducted

TABLE 3

SUMMARY OF DATA SOURCES AND USES IN ADJUSTING CHINA'S LIVESTOCK SUPPLY AND DEMAND SERIES

Data Source	Acronym (1)	Data Collection Entity (2)	Years of Coverage (3)	Sample Size (Households) (4)	Uses (5)
Urban Household Income and Expenditure Survey	Urban HIES	CNSB, urban survey team	1980–99	In 1999, 40,044 urban households	Baseline for annual urban household livestock commodity consumption (by commodity) Trends for out-of-home consumption of livestock products for urban households
Rural Household Income and Expenditure Survey	Rural HIES	CNSB, rural survey team	1980–99	In 1999, 67,430 rural households	Baseline for annual rural household livestock commodity consumption (by commodity) Trends for out-of-home consumption of livestock products for rural households Annual number of slaughtered animals and meat production by rural households (by commodity)
Agricultural Census (31 provincial agricultural census publications)	1997 Ag Census	National and Provincial Agricultural Census Office	1996	Complete census data (214 million households)*	Number of slaughtered animals (by commodity)
CCAP and CARD livestock supply and demand survey†	CCAP Survey	Primary data collection by CCAP/CARD	1998	250 rural households and 250 urban households	Composition of out-of-home consumption for both rural and urban households (e.g., allows us to know how much meat urban and rural households are consuming when they eat outside the home) Provides alternative (more comprehensive) estimates of total consumption of livestock commodities against which we can compare HIES demand levels. We use our information to make additional adjustments to pork, poultry, and egg consumption series

* In addition to the 200 million rural households, the census also surveyed all agricultural enterprises, including commercial livestock enterprises.

† The Center for Chinese Agricultural Policy (CCAP) is part of the Chinese Academy of Science's Institute of Geographical Sciences and Natural Resource Research, and the Center for Agricultural and Rural Development (CARD) is at Iowa State University.

in rural areas (table 3, row 2). First, as in the case of the urban survey, we use a variable that has been asked of rural households about their total expenditures on out-of-home consumption. In the case of the rural survey, this question has been asked since 1983. This information is used to adjust rural livestock consumption series.

We also use information from the rural survey's production block (table 3, row 2). At the end of each year, CNSB enumerators make a special visit to the respondents to ask a series of questions about the household's annual production activities. In particular, the survey asks questions about the household's livestock output, including the number of animals that they slaughtered and the quantity of meat that they produced. Such data are collected on a disaggregated basis for swine, poultry, beef cattle, sheep and goats, and eggs. We use this information in conjunction with data from 1997 Ag Census (described below) to make adjustments to the livestock production series.

As a check on (and point of calibration for) the production information from the rural HIES data, we also use information generated by the 1997 national census of agriculture (table 3, row 3). Supported by both international and domestic funding sources and run by national and provincial agricultural census offices, this survey's main objective was to provide sectoral officials with an accurate and unbiased baseline that reflects the state of China's rural sector.[16] The survey covered all rural households plus all nonhousehold agricultural enterprises (e.g., state-owned farms and commercial firms engaged in agricultural production). One of the main objectives of the survey was to come up with an accurate estimate of the size of the livestock economy. To meet this objective, the survey asked all rural households and nonhousehold agricultural enterprises about the number of animals that they slaughtered (though not the quantity of meat produced) during the census period January 1 to December 31, 1996. As in the HIES, census respondents provided their annual production information for swine, poultry, beef cattle, and sheep and goats (but did not supply information on egg production). In this article, we assume that these data provide the most accurate and complete picture of China's livestock production in the 1990s, and all data series are calibrated using these numbers. In all cases, the 1996 observations in our revised data series are exactly those figures generated by the agricultural census.

However, even with access to the data from national surveys, we still found ourselves lacking two key pieces of information: the composition of out-of-home consumption and estimates of total consumption of livestock products by urban and rural household (both direct and indirect, including that which is embodied in processed foods). In order to have a basis for estimating these two variables, we conducted our own survey in 1999 (table 3, row 4).[17] In addition to information about the basic characteristics of the household and its individuals, enumerators asked detailed information about the household's in-home food expenditures and consumption of pork, poultry, beef, mutton, and eggs. Since our survey focused on livestock product consumption and since livestock products in most rural households in China are

consumed unequally throughout the year, we also specifically asked households about their expenditures and consumption of livestock products during major festivals and holidays.

In another section, enumerators asked households about their consumption of livestock products when they were not at home. Using the same strategy as the HIES, enumerators asked households to report their total expenditures on out-of-home consumption. In addition, our survey asked for detailed information about the composition of each household member's out-of-home consumption. Using this information in conjunction with our estimates of in-home consumption, we were able to create estimates of total per capita animal product out-of-home consumption.

Finally, we also need estimates of the consumption by migrants. Based on our work elsewhere, we come up with estimates of the number of migrants that are living and working in cities.[18] We then use these data with information about the consumption patterns of migrants.[19]

IV. Adjustments of Demand and Supply Series

In this section, we discuss how we adjust data series for China's livestock demand and supply. To do so, we first lay out our assumptions for the demand side. Next we discuss the strategy to adjust the supply side. Based on these strategies, in the next section, we empirically make adjustments to the official livestock demand and supply series. Overall, the strategy has three main parts. First, we adjust existing consumption data upward to account for livestock products that are consumed out of the home (including animal products consumed in restaurants and those consumed by rural migrant laborers). Second, we adjust existing production downward, eliminating the biases that have been introduced by the statistical reporting system for output since the late 1980s. Finally, in the case of pork, poultry, and eggs, we also make an additional upward adjustment to consumption in order to account for the animal products that are missed by the HIES survey (e.g., pork, poultry, and eggs that are consumed in processed foods).

To create new series of believable data for China's livestock sector, we need to rely on several categories of assumptions regarding the source and nature of the discrepancies. In particular, we make assumptions about economic behavior, especially when adjusting the consumption data. In addition, we also make a series of assumptions about statistical accuracy and misreporting and how they have changed over time. Finally, we rely on several implicit assumptions about changes (or consistency) of technical parameters over time.

Demand Side Assumptions and Strategies

To make the initial adjustment to the demand side data, we rely on three specific assumptions. First, we assume that the HIES data, both urban and rural, accurately measure total out-of-home food expenditures. Second, although we know how much the household spent on out-of-home consumption,

we do not believe that commodity-specific consumption statistics based on HIES data account for the part of the consumption that takes place outside of the household. In other words, statistics reporting the quantity of meat consumed that are based on HIES data are underreported primarily because respondents generally failed to include their out-of-home food consumption in this statistical category. Zhong also believes this is the case.[20] Third, to get an assessment of the impact that the trend toward more out-of-home expenditure has on animal product demand, we assume that meat consumption that is embodied in out-of-home expenditures rises at the same rate as total expenditures on out-of-home consumption. In fact, this is probably a conservative assumption since, over time, as food expenditures have risen, we would expect that meat demand would rise relatively faster than that of other foods.[21] Based on these three demand side assumptions, we can see that two pieces of information that are needed to adjust the demand side of meat data series are precisely those that we discussed in the previous section: the trend in out-of-home consumption during the last 2 decades and the proportion of total food consumed out of the home that is made up of animal products (table 4, rows 1–5).

After the corrections for out-of-home consumption, we also need to correct these data to account for the increasing fraction of the rural labor force that has temporarily moved into urban areas to work as migrant laborers.[22] Although in 1990 only 9% of the rural labor force out-migrated, by 2000 nearly 20% lived outside their home while they were working.[23] As shown by J. Huang and S. Rozelle, when migrants move from the countryside to the city, changing preferences make them alter their dietary patterns (even holding income and price changes constant) within a very short time.[24] The average rural migrant almost immediately increases the proportion of income spent on meat products. Following estimates provided by Huang and Bouis, we assume that the meat consumption of migrants is halfway between the level of consumption for rural and urban individuals.[25] This new consumption pattern is assumed to be adopted by all of the laborers in the migrant labor force and their family members. It is assumed that a family member accompanies, on average, one in five migrants.

Adjustments also need to be made for China's growing consumption of processed food products at home. Many of these products, such as frozen meat-filled pastries, dumplings, and precooked noodle mixes, contain meat. When questioning CNSB survey respondents about how they recorded such products, most said they often did not count them as meat products. In fact, during our own field survey we found that the average level of consumption of animal products was significantly more than that recorded by HIES enumerators (table 4, rows 6–10). For example, our survey found that per capita pork consumption for urban residents was 21.9 kilograms, about 37% more than that reported in HIES (row 6). X. Yuan, J. Wang, and Q. Han found the same result in their survey of rural and urban consumers (cols. 4, 8).[26] Therefore, for the cases of pork, poultry, and eggs, we believe that we are justified

TABLE 4

EVIDENCE OF UNDERREPORTING OF OUT-OF-HOME AND IN-HOME URBAN AND RURAL LIVESTOCK CONSUMPTION BY THE CHINA NATIONAL STATISTICAL BUREAU'S HOUSEHOLD INCOME AND EXPENDITURE SURVEY (HIES), 1998

	Urban Residents				Rural Residents			
	National HIES*	Four Province HIES Mean†	CCAP Survey‡	Yuan, Wang, and Han Data§	National HIES*	Four Province HIES Mean†	CCAP Survey‡	Yuan, Wang, and Han Data§
Per capita consumption, out of the home:								
Pork	…	…	5.30	8.17	…	…	1.38	1.85
Poultry	…	…	1.10	5.25	…	…	.76	.70
Eggs	…	…	1.20	2.06	…	…	.41	.94
Beef	…	…	1.00	…	…	…	.10	…
Mutton	…	…	.45	…	…	…	.18	…
Per capita consumption, in home:								
Pork	15.88	18.33	21.88	22.55	11.89	11.95	12.42	17.19
Poultry	7.22	7.86	7.99	4.99	2.33	2.27	2.54	4.13
Eggs	10.76	11.00	15.85	13.78	4.11	7.05	7.04	6.10
Beef	2.10	…	3.08	…	.59	…	1.40	…
Mutton	1.24	…	.69	…	.72	…	.30	…

NOTE.—Beef and mutton data are not disaggregated by province. Yuan, Wang, and Han also do not provide separate estimates for beef and mutton. For complete discussion of data sources, see text and table 3.

* Per capita consumption data (average for all of China's provinces) come from the 1999 urban and rural HIES. The HIES per capita consumption data provide only the quantities of animal products consumed in the home and exclude per capita quantities consumed out of the home.

† Average of 1998 HIES per capita consumption for the four provinces (Jilin, Shandong, Sichuan, and Chongqing) in which the CCAP survey was conducted..

‡ These CCAP survey data were collected jointly by the CCAP and the CARD.

§ Xueguo Yuan, Jimin Wang, and Qing Han, "Were Chinese Livestock Statistics Inflated?" (in Chinese), *Chinese Rural Economy* 1 (2001): 48–54.

in making further adjustments based on the Center for Chinese Agricultural Policy (CCAP) survey data.[27]

Supply Side Assumptions and Strategies

To make supply side adjustments, we also rely on three assumptions. First, we assume that the data published in China's national statistical and agricultural yearbooks were correct in the early and mid-1980s (although they began to be overstated in the late 1980s). During this period, we are assuming that the annual census of livestock that was carried out each year by village accountants was subject to less distortions and that the HIES production data were based on information that is less representative than that generated by the current HIES. Indeed, in the early 1980s, CNSB surveyed only 15,000 rural households, whereas they now sample more than 65,000.

Second, we assume that the production data collected by the rural HIES in the late 1980s and 1990s accurately captures the household's livestock production activities, a fact that can be used to check the accuracy of the 1997 Ag Census data. Hence, for those livestock categories for which production is dominated by household production (e.g., swine), trends after the late 1980s based on the rural HIES production data provide a reasonably accurate estimate of national production. We recognize, however, that in the case of some livestock categories (e.g., poultry and beef), nonhousehold enterprises contribute a significant part of the production. In these cases, when we compare our data to the 1997 Ag Census data (which contains both household and commercial output), we can use the proportion of total production that comes from commercial sources (which is reported separately in the Ag Census) to get an estimate of commercial production. The commercial production from the Ag Census can then be added to an estimate of household production from the HIES survey to assess the overall accuracy of the 1997 Ag Census data. Interestingly, this exercise shows that, in fact, rural household livestock production data are overstated somewhat (perhaps, we conjecture, because the sample misses the poorest households who, as shown by J. Chen, produce relatively fewer animals).[28]

Finally, since the 1997 Ag Census was the most comprehensive and carefully monitored agricultural and rural development data collection effort that China has ever undertaken, we assume that the number of slaughtered animals for each category (e.g., swine, poultry) from this source constitutes our best estimate of livestock production. Unfortunately, the Ag Census only provides animal numbers (slaughtered), unlike the yearbook and the HIES production data, which provide both animal numbers (e.g., how many hogs were slaughtered) and meat production estimates (e.g., an estimate of how much pork came from the hogs that were slaughtered). In order to provide an estimate of the meat produced in 1996 that is consistent with the 1997 Ag Census' animal production data, we multiplied the number of animals by a coefficient representing the average carcass weight. This coefficient is derived

from the yearbook by dividing China's meat production for each animal product by the number of animals.[29]

Given the assumptions above, we believe that we can create a complete and consistent picture of China's livestock production, following a strategy that has three defining characteristics. First, our estimates from 1980 to 1986 are exactly those that appear in CNSB's yearbook during that time. Second, since we assume that 1986 to 1988 are the last years that the data generated by the statistical yearbooks were accurate, we set 1987 equal to the average of 1986 to 1988 (doing so to avoid distortions that might have arisen had we chosen a single year). Third, since we assume that we have an accurate assessment for the numbers of animals for 1996 (based on the 1997 Ag Census), the 1996 data point in our production series is always exactly that found in the Ag Census. Furthermore, we believe that the rural HIES production data tell us something about livestock's year-to-year production variability. Hence, as we believe this information (i.e., observations from 1980 to 1987 and an observation in 1996) to be accurate, our remaining challenge is to figure out a way to estimate accurately livestock production trends since the late 1980s.

To provide estimates of production from 1988 to 1999 (except for 1996), we create point α, which is our estimate of 1987 production. Next, we define point β, which is set equal to the figure reported in data from the 1997 Ag Census. In the third step, we fit a linear trend line from α (1987) through β (1996) extending to the final point of our adjusted data series in 1999. Finally, in order to maintain the year-to-year variability contained in the HIES household production data in our adjusted data series, we fit a regression line through the HIES household production data (from 1987 to 1999), and we add the residuals (except for those for 1987 and 1996) from the regression to the fitted trend line in step three. It is in this way that our adjusted production data have the special characteristic that they always pass through two key points, α and β, and retain the variability of the HIES data.

V. Revised Livestock Demand and Supply Series

In this section, we present the results of our work to create adjusted series for China's livestock demand and supply. To do so, we first examine how the demand and supply series converge as we make our three adjustments (defined above). At each step, we will assess how well our adjusted series are doing in terms of the equivalency criterion. If our adjustments help the demand and supply data become more consistent with one another, we should find that the ratios in the late period that were reported in table 1 (and tested in table 2) should improve by moving closer together (or becoming closer to one). In addition, we also examine whether or not the revised series meet the other criteria (i.e., whether or not the feed use implied by livestock production figures is roughly equivalent to the nation's feed grain production and how well the series seem to reflect the trends that we are observing in China).

Correcting aggregate consumption data to reflect the fact that urban and rural residents consume significant quantities of meat outside the home is partly responsible for shifting the consumption series up and begins to close the gap between demand and supply.[30] According to the CCAP survey (which asked about the composition of food eaten out of the home) and the urban HIES and rural HIES surveys (which asked about total out-of-home expenditure data), urban residents consumed 1.00 kilograms of pork in 1990 and 5.83 kilograms of pork in 1999 out of the home (col. 5). In 1999, rural residents consumed 1.45 kilograms of pork (col. 6). According to these findings, when compared to the HIES-based per capita pork consumption figures, a significant fraction (5.83/16.91, or 34%) of China's urban pork consumption is consumed in restaurants and other places out of the home. Likewise, rural out-of-home consumption accounts for 12% of pork consumption by rural residents (1.45/11.68). H. Ma, J. Huang, and S. Rozelle found similar patterns of out-of-home consumption of poultry and other animal products.[31]

The rise of migration also has played a role in increasing the divergence between livestock supply and demand statistics. While counted as rural residents by the HIES system and implicitly assigned per capita consumption levels of pork of 10.5 kilograms in 1990 and 11.7 kilograms in 1999, migrants actually consumed significantly higher levels.[32] For example, the average migrant consumed 14.3 kilograms per capita in 1999, an increase of 22% over his counterpart who still lived in rural China.[33] When this gap is multiplied by more than 100 million migrants and their families (assumed to be an additional 20% more), it can account for a lot of the missing pork demand.[34] The similar pattern can be found for poultry and other animal products.[35]

After adjusting for out-of-home consumption and the increased consumption by migrants, aggregate pork consumption rises to 27.21 million metric tons in 1999 instead of 21.94 million metric tons (table 5, cols. 1–2). Between 1987 and 1998, the adjusted consumption series rises at 2.96% annually, more than twice as fast as the unadjusted one (bottom row).[36]

The rises in pork consumption significantly affect the observed supply-demand ratio for pork. Whereas the ratio of supply to demand of the unadjusted data rises to 1.83 by 1999 (table 5, col. 6), after correcting the data for out-of-home consumption and the increased consumption by migrants, the ratio falls to 1.47 (col. 7). The first correction to consumption, then, is important and helps reduce the gap between demand and supply, but it does not close it entirely.

A similar narrowing is found when the same adjustments are made for poultry (table 6) and the other livestock products.[37] For example, the ratio for poultry (the consumption of which rises annually by 4.7% instead of 6.2%; table 6, cols. 1–2) falls from 1.94 for the unadjusted series (col. 6) to 1.53 after we adjust the consumption data to account for out-of-home consumption and the increased consumption by migrants (col. 7). As with the case of pork, the adjustments close the poultry gap but do not eliminate it.

Adjustments to production affect the demand and supply series even

TABLE 5

Reconciling China's Pork Production (Supply) and Consumption (Demand) Statistical Series, 1980–99

Year	Aggregate Demand Based on HIES and Trade (mmt)* (1)	Adjusted Demand for Omission of Out-of-Home and Migrant Consumption (mmt)† (2)	Adjusted Demand for Omission of In-Home Consumption (mmt)‡ (3)	Reported Aggregate Pork Supply from Yearbook (mmt) (4)	Adjusted Aggregate Pork Supply for Overreporting (mmt) (5)	Various Supply/Demand Ratios (to Assess the Consistency of Data Series Adjustments)			
						4/1 (6)	4/2 (7)	5/2 (8)	5/3 (9)
1980	10.47	10.63	10.63	11.34	11.34	1.08	1.07	1.07	1.07
1981	11.84	12.04	12.04	11.88	11.88	1.00	.99	.99	.99
1982	13.23	13.46	13.46	12.72	12.72	.96	.94	.94	.94
1983	14.63	14.91	14.91	13.16	13.16	.90	.88	.88	.88
1984	16.07	16.39	16.39	14.45	14.45	.90	.88	.88	.88
1985	16.73	17.14	17.14	16.55	16.55	.99	.97	.97	.97
1986	18.76	19.23	19.23	17.96	17.96	.96	.93	.93	.93
1987	18.40	19.01	19.01	18.35	18.83§	1.00	.97	.99	.99
1988	17.56	18.30	18.47	20.18	19.92	1.15	1.10	1.09	1.08
1989	18.13	18.97	19.31	21.23	20.06	1.17	1.12	1.06	1.04
1990	18.91	19.79	20.31	22.81	21.01	1.21	1.15	1.06	1.03
1991	20.20	21.18	21.90	24.52	23.58	1.21	1.16	1.11	1.08
1992	19.69	20.98	21.92	26.35	24.43	1.34	1.26	1.16	1.11
1993	19.95	21.58	22.75	28.54	25.58	1.43	1.32	1.19	1.12
1994	19.49	21.74	23.13	32.05	25.98	1.64	1.47	1.20	1.12
1995	20.03	23.02	24.65	36.48	26.59	1.82	1.58	1.15	1.08
1996	21.81	25.43	27.31	31.58	28.59§	1.45	1.24	1.12	1.05
1997	20.54	24.53	26.67	35.96	29.75	1.75	1.47	1.21	1.12
1998	21.50	26.15	28.56	38.84	29.82	1.81	1.49	1.14	1.04
1999	21.94	27.21	29.91	38.91	32.00	1.77	1.43	1.18	1.07
Growth‖	1.43	2.96	3.76	6.57	4.45	5.04	3.50	1.45	.66

Source.—Hengyun Ma, Jikun Huang, and Scott Rozelle, "Reassessing China's Livestock Statistics: Analyzing the Discrepancies and Creating New Data Series," working paper (Center for Chinese Agricultural Policy, Chinese Academy of Sciences, and Department of Agricultural and Resource Economics, University of California, Davis, 2002).

Note.—mmt = million metric tons.

* Figures in col. 1 are the same as table 1, col. 1, and are calculated from data shown in Ma, Huang, and Rozelle, app. 1, col. 9.

† Adjustments to create figures in col. 2 are shown in Ma, Huang, and Rozelle, app. 2, col. 9, and app. 4, col. 16. Adjustments include those due to omission of out-of-home consumption of urban and rural residents and to differences in consumption patterns of traditional rural households and of rural migrants and their families.

‡ Adjustments to create figures in col. 3 are shown in Ma, Huang, and Rozelle, app. 5, col. 12.

§ These figures are the 3-year averages of yearbook production data from 1986–88 and the production supply generated from the 1997 Ag Census.

‖ Annual growth rate between 1987 and 1998, where 1987 and 1998 are 3-year averages centered on 1987 and 1998.

TABLE 6

Reconciling China's Poultry Production (Supply) and Consumption (Demand) Statistical Series, 1980–99

Year	Aggregate Demand Based on HIES and Trade (mmt)* (1)	Adjusted Demand for Omission of Out-of-Home and Migrant Consumption (mmt)† (2)	Adjusted Demand for Omission of In-Home Consumption (mmt)‡ (3)	Reported Aggregate Poultry Supply from Yearbook (mmt) (4)	Adjusted Aggregate Poultry Supply, for Overreporting (mmt) (5)	Various Supply/Demand Ratios (to Assess the Consistency of Data Series Adjustments)			
						4/1 (6)	4/2 (7)	5/2 (8)	5/3 (9)
1980	.88	.88	.88	.94	.94	1.07	1.06	1.06	1.06
1981	1.02	1.07	1.07	1.03	1.03	1.00	.96	.96	.96
1982	1.25	1.32	1.32	1.18	1.18	.94	.90	.90	.90
1983	1.35	1.43	1.43	1.30	1.30	.96	.91	.91	.91
1984	1.52	1.62	1.62	1.44	1.44	.95	.89	.89	.89
1985	1.77	1.88	1.88	1.60	1.60	.90	.85	.85	.85
1986	1.95	2.07	2.07	1.88	1.88	.96	.91	.91	.91
1987	2.03	2.19	2.19	2.19	2.27§	1.08	1.00	1.04	1.04
1988	2.27	2.46	2.50	2.74	2.78	1.21	1.12	1.07	1.05
1989	2.45	2.67	2.75	2.82	3.08	1.15	1.06	1.05	1.02
1990	2.68	2.91	3.03	3.23	3.44	1.21	1.11	1.05	1.01
1991	2.82	3.08	3.25	3.95	3.91	1.40	1.28	1.13	1.07
1992	3.18	3.52	3.73	4.54	4.44	1.43	1.29	1.13	1.07
1993	3.41	3.84	4.09	5.74	4.78	1.68	1.50	1.13	1.06
1994	3.64	4.23	4.54	7.55	5.09	2.07	1.78	1.12	1.04
1995	3.95	4.73	5.09	9.35	5.57	2.36	1.97	1.13	1.05
1996	4.28	5.28	5.69	8.96	6.06§	2.09	1.70	1.15	1.06
1997	4.92	6.05	6.51	9.55	6.67	1.94	1.58	1.15	1.07
1998	5.02	6.35	6.86	10.23	6.86	2.04	1.61	1.18	1.09
1999	5.58	7.05	7.63	11.16	7.35	2.00	1.58	1.17	1.08
Growth‖	8.61	10.15	10.87	14.74	11.62	5.70	4.23	1.37	.71

Source.—Hengyun Ma, Jikun Huang, and Scott Rozelle, "Reassessing China's Livestock Statistics: Analyzing the Discrepancies and Creating New Data Series," working paper (Center for Chinese Agricultural Policy, Chinese Academy of Sciences, and Department of Agricultural and Resource Economics, University of California, Davis, 2002).

Note.—mmt = million metric tons.

* Figures in col. 1 are the same as table 1, col. 4. They are calculated from data shown in Ma, Huang, and Rozelle, app. 1, col. 10.

† Adjustments to create figures in col. 2 are shown in Ma, Huang, and Rozelle, app. 2, col. 10, and app. 4, col. 17. Adjustments include those made due to omission of out-of-home consumption by urban and rural residents and to consumption by rural migrant laborers and their families.

‡ Adjustments to create figures in col. 3 are shown in Ma, Huang, and Rozelle, app. 5, col. 13.

§ These figures are the 3-year averages of yearbook production data from 1986–88 and the meat production generated from the 1997 Ag Census.

‖ An annual growth rate between 1987 and 1998, where 1987 and 1998 are 3-year averages centered on 1987 and 1998.

more (tables 5–6). When production trends are forced to go through and become consistent with yearbook data in the late 1980s and the 1997 Ag Census data in 1996 (the data points we believe to be relatively accurate), the reported increases in production are dampened considerably. For example, whereas the unadjusted pork production data were shown to have risen by 6.57% annually between 1987 and 1998, after adjusting the data, the pork production series rose only 4.45% (table 5, cols. 4–5). The growth rates in production for other animal products, such as poultry, fell even more (by nearly 3 percentage points from 14.74% to 11.62%; table 6, cols. 4–5). When comparing pork demand adjusted for out-of-home consumption (table 5, col. 2) to both the unadjusted and adjusted production data series (cols. 4–5), the consistency ratio falls sharply from 1.43 to 1.18 (cols. 7–8). The poultry ratios collapse even more, falling from 1.58 to 1.17, implying that the degree of overreporting of poultry was even greater than that of pork (table 6, cols. 7–8).

Underreporting of total animal product consumption due to incomplete enumeration of in-home consumption of pork, poultry, and eggs (e.g., significant quantities of pork being incorporated into prepared goods that are not recorded by the HIES survey as pork consumption) also has played a role in the slow growth rates of animal product consumption.[38] In the case of urban pork consumption, according to the CCAP survey, in 1998, households were annually consuming 3.33 kilograms per capita more than they were reporting to HIES enumerators.[39] By 1999 (we extended estimates back to 1988 and forward to 1999; see discussion in previous section), unreported in-home urban pork consumption reached 3.63 kilograms, 21% higher than the HIES number (3.63/16.91). Although less than the amount unreported due to the omission of out-of-home consumption (e.g., omission of out-of-home urban pork consumption was 34%), the impacts in 1999 on rural pork consumption (5%) and urban and rural poultry consumption (9% and 12%, respectively) are significant.

After making the final adjustment (for in-home consumption) to pork, poultry, and eggs, the supply and demand series for the five animal-product categories show nearly complete convergence. For example, the annual growth rate of pork consumption from 1987 to 1998 increases from 2.96% (which was the growth rate after adjustments were made for out-of-home consumption) to 3.76% (table 5, cols. 2–3). The rise in consumption, after adjusting for the omission of in-home consumption, leads to another decline in the consistency ratio of pork production to consumption. The consistency ratio for pork supply and demand in 1999 falls from 1.18 to 1.07 (cols. 8–9). In fact, the consistency ratios after the final adjustments are almost one after 1987 (the average of the ratio is only 1.07 from 1987 to 1999). The other animal products, such as poultry, show similar patterns of convergence. The final adjustment for poultry consumption (which increases the 1987–98 poultry consumption annual growth rate to 10.87) makes the consistency ratio fall from 1.17 to 1.08 (table 6, cols. 8–9).

TABLE 7

CONSISTENCY TESTS FOR THE ADJUSTED SUPPLY AND ADJUSTED DEMAND SERIES, 1980–99

	DEPENDENT VARIABLE, R_{it} = Adjusted Supply/Adjusted Demand				
INDEPENDENT VARIABLE	Pork	Poultry	Eggs	Beef	Mutton
Tests for structural change:					
$T_{t\leq 1987}$	−.01	−.00	.00	−.01	−.01
	(1.03)	(.06)	(.21)	(1.19)	(1.56)
$T_{t>1987}$	.01*	.01*	−.00**	.01**	−.01
	(2.36)	(3.66)	(1.96)	(3.76)	(.63)
Adjusted R^2	.64	.69	.34	.75	.20
Tests for convergence of supply/demand ratio to one:					
Before 1987:					
$T_{t\leq 1987}$	−.01	−.01	−.00	−.00	−.01
	(.98)	(.55)	(.05)	(.01)	(1.89)
Intercept	1.01***	.97***	1.09***	.72***	1.05***
	(20.46)	(15.87)	(22.06)	(11.45)	(27.22)
F-statistic (test: intercept = 1)	.03	.24	3.64	18.99***	1.82
After 1987:					
$T_{t>1987}$	.00	−.00**	−.00	.00	−.00
	(.20)	(2.85)	(1.79)	(.53)	(0.21)
Intercept	1.07***	.99***	1.06**	.96***	1.02***
	(24.35)	(43.44)	(59.62)	(12.10)	(20.57)
F-statistic (test: intercept = 1)	2.57	.11	3.18	.20	.32

NOTE.—For the tests of structural change (rows 1–3), the equation regressing a time trend from two periods on the supply/demand ratio is run with an intercept; parameters are not shown. Two separate within-period equations are used to test for convergence of supply/demand ratio to one (rows 4–6, and rows 7–9). The figures in parentheses are t-statistics. To test the null hypothesis that the supply/demand ratio is equivalent to one, we test for the significance of the intercept. If F-statistics (rows 6, 9) are greater than 4, we reject the null hypothesis.

* Significant at 10% level.

** Significant at 5% level.

*** Significant at 1% level.

A final set of statistical tests show that after making the adjustments to supply and demand, our new series almost certainly meet the equivalency criteria. Like the series between 1980 and 1987 (which displayed the characteristic of supply equaling demand), after the final adjustments to the demand and supply series, the statistical tests for the consistency ratios demonstrate that the revised series meet the equivalency criteria (table 7). Though the coefficients of $T_{t>1987}$ are still significant, the absolute effect of this variable is small. For example, the consistency ratios for pork and poultry are only 0.01 between 1988 and 1999, meaning that the ratio only increased by 0.01 annually after 1987 (row 2). More important, F-tests show that the coefficients of intercept are convergent to one (rows 6, 9). Although the coefficient of $T_{t>1987}$ for poultry is still significant, its impact on the ratio is almost equal to zero.

Graphically, our adjusted series in panels A and B of figure 1 (represented

by the two graph lines that are now inside the two unadjusted series) show the result of our work to make the livestock demand and supply series consistent. Since the late 1980s, the unadjusted pork production series (uppermost) that was reported by CNSB has increased more rapidly than the adjusted one (the second uppermost); in contrast, the unadjusted pork consumption series (lowermost) has increased but much more slowly than the adjusted one (the second lowermost, panel A). In addition to differing from the unadjusted series, both the adjusted production and the adjusted consumption series follow strikingly common paths during the entire reform era (both the 1980s and the 1990s). At its widest gap, unadjusted production had grown to a level 82% higher than unadjusted consumption. In contrast, the gap in the adjusted series is trivially narrow. The trends for the unadjusted and adjusted poultry series are similar; the gap in the unadjusted series that reached its peak in 1998 (104%) is virtually gone in the adjusted series (panel B). The data series for eggs, beef, and mutton create similar pictures.[40]

Interestingly, although our adjustments dramatically narrowed the gap that appeared between the official supply and demand statistics (e.g., pork from 81% to less than 5% in 1998), the magnitude of this narrowing would have been greater had not CNSB adjusted its output data in response to the 1997 census. In the 1997 yearbook, official statistics reported 1996 meat output to be 40.38 million metric tons. This figure is a staggering 85% greater than CNSB's 1996 consumption figure. After the publication of the census data, the 1998 yearbook revised the 1996 meat output statistics to be 31.6 million metric tons (the figure we report on fig. 1, panel A, for hog output). In making these adjustments, CNSB is implicitly admitting that its production figures were overstated even though it makes the adjustment without any explanation. However, even after the adjustment, two facts still make the CNSB production series questionable. First, although CNSB apparently adjusted its output statistics to make the series more consistent with the census data, its 1996 hog output figure (31.6 million metric tons) is still 10% higher than the figures published by the national census office. Even more troubling, after 1996, despite the fact that it was the unbelievably high rate of growth of reported supply that led to the inflation of national livestock statistics, the growth rate of CNSB's production data is almost as fast as before, even though the economy slowed noticeably in the late 1990s. Hence, the actions of CNSB to adjust its data give credibility to our strategy, and its inability to reduce the growth rate from its statistical sources means that our adjusted series may be of greater value to those wanting to understand China's livestock economy.

A decomposition analysis summarizes our adjustments and accounts for the changes in the livestock supply and demand series that makes them consistent with one another (table 8). In the case of pork in 1999, for example, when using the unadjusted series, supply is more than 17 million metric tons more than demand (col. 1, row 1). In the course of our adjustments, the adjustment down of supply accounted for 41% of the reconciliation effort (col. 5). Of the adjustments to consumption, 29% of the gap was eliminated

TABLE 8

DECOMPOSITION OF TOTAL GAP BETWEEN UNADJUSTED SUPPLY (Production) AND UNADJUSTED DEMAND (Consumption) LIVESTOCK STATISTICAL SERIES IN CHINA, 1990 AND 1999

Series	Total Gap* (Million Metric Tons) (1)	Source of Total Gap (%)				
		Out-of-Home† (2)	Migrant‡ (3)	In-Home§ (4)	Production‖ (5)	Other (6)
In 1999:						
Pork	16.97	29	5	16	41	9
Poultry	5.58	21	6	10	52	10
Eggs	13.33	3	7	34	53	3
Beef	3.19	21	6		69	4
Mutton	1.33	30	2		65	3
In 1990:						
Pork	3.89	17	6	14	46	17
Poultry	.55	32	11	22	30	5
Eggs	3.17	4	4	66	17	9
Beef	.14	48	20		30	2
Mutton	.22	26	13		44	17

SOURCE.—Hengyun Ma, Jikun Huang, and Scott Rozelle, "Reassessing China's Livestock Statistics: Analyzing the Discrepancies and Creating New Data Series," working paper (Center for Chinese Agricultural Policy, Chinese Academy of Sciences, and Department of Agricultural and Resource Economics, University of California, Davis, 2002).

* The figures represent the total gap (in million metric tons) between reported production data from yearbooks and reported consumption from HIES and trade statistics, measured in carcass weight (e.g., the total gap for pork is pork supply [table 1, col. 2] minus pork demand [table 1, col. 1]).

† Due to the omission of out-of-home consumption. For example, percent of total pork gap accounted for by out-of-home pork consumption is calculated by dividing adjustments made to pork consumption due to omission for out-of-home pork consumption (Ma, Huang, and Rozelle, app. 2, col. 9, minus app. 1, col. 9) by total pork gap (this table, col. 1).

‡ Due to the omission of migrant consumption. For example, percent of total pork gap accounted for by migrant pork consumption is calculated by dividing adjustments made to pork consumption due to omission for migrant pork consumption (Ma, Huang, and Rozelle, app. 4, col. 16, minus app. 2, col. 9) by total pork gap (this table, col. 1).

§ Due to the omission of in-home consumption. For example, percent of total pork gap accounted for by in-home pork consumption is calculated by dividing adjustments made to pork consumption due to omission for in-home pork consumption (Ma, Huang, and Rozelle, app. 5, col. 12, minus app. 4, col. 16) by total pork gap (this table, col. 1).

‖ Due to overreported production. For example, percent of total pork gap accounted for overreporting pork production is calculated by dividing the overreported number (table 5, col. 4 minus col. 5) by total pork gap (this table, col. 1).

by adjusting for out-of-home (col. 2). Adjustments for migration and in-home consumption account for 5% and 16% (cols. 3–4), respectively. There is a residual of 9% after the four adjustments (col. 6). Clearly, according to this analysis, the overreporting of supply has not only created the most problems for pork but, in 1999, also accounts for an even larger part of the discrepancies for poultry (52%), eggs (53%), beef (69%), and mutton (65%, col. 5, rows 2–5).

In addition to meeting tests for consistency, our new series also meet

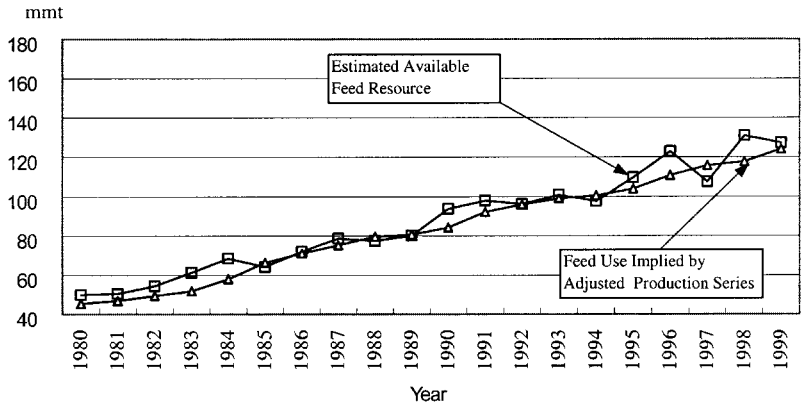

FIG. 2.—Estimated available feed grain and feed use implied in adjusted production in China, 1980–99. Estimated available feed resource mainly includes corn, wheat bran, sweet potato, rice, and other coarse grains. Feed use implied by adjusted production is estimated using livestock production statistics reported in table 5, col. 5 (pork), in table 6, col. 5 (poultry), and in Hengyun Ma, Jikun Huang, and Scott Rozelle, "Reassessing China's Livestock Statistics: Analyzing the Discrepancies and Creating New Data Series," working paper (Center for Chinese Agricultural Policy, Chinese Academy of Sciences, and Department of Agricultural and Resource Economics, University of California, Davis, 2002), app. 7, col. 5 (eggs), app. 10, col. 5 (beef), and app. 11, col. 5 (mutton), and using standard feed-meat conversion coefficients. See text for details.

the two other criteria. To demonstrate that our new livestock production series are consistent with national feed grain statistics, we use the same assumptions about feed grain consumption that we used previously.[41] Applying the feed grain use conversion to the animal production trends, the revised livestock supply series generates a derived demand for feed series that is much more consistent than the unadjusted one (fig. 2). While at its widest point, the unadjusted feed demand was 53% greater than feed supply, when using the adjusted livestock numbers, after 1988, the average gap between feed supply and demand is only 3%. Our data series are also consistent with some commonly observed trends in society. Unlike the unadjusted figures, the rise in pork consumption that appears in our revised series is what one expects, given the rapid rise in incomes and the noticeable increase in meat consumption during the 1990s. Unsurprisingly, the single biggest source of upward adjustment of pork (and poultry) is in the consumption of meat out of the home. Anyone who is in China for any appreciable length of time will notice not only the large and growing number of restaurants but also the high level of meat consumption in them. Furthermore, while livestock production has risen in recent years, there is absolutely no way that the growth rates implied by the yearbook production figures could have occurred and been sustained for the entire 1990s. In short, the new rates are more believable.

TABLE 9

CEREAL NET IMPORT PREDICTIONS BASED ON VARIOUS MEAT ESTIMATE DATA SETS
(Million Metric Tons)

Year	CNSB	CCAP	Fuller, Hayes, and Smith
2005	73.5	24.2	−15.4
2006	76.8	26.7	−13.5
2007	82.0	30.9	−10.3
2008	87.8	35.6	−6.6
2009	93.4	40.0	−3.2
2010	98.7	44.1	−.1

SOURCE.—Simulation results from CAPSiM model were developed by the CCAP. See Jikun Huang, Scott Rozelle, and Mark W. Rosegrant, "China's Food Economy to the Twenty-first Century: Supply, Demand, and Trade," *Economic Development and Cultural Change* 47 (1999): 737–66.

NOTE.—Cereal net imports include only milled rice, wheat, maize, potatoes, sweet potatoes, and other coarse grains.

VI. Implications of the Adjusted Series for China's Cereal Trade Predictions

To assess the importance of making adjustments to livestock data, we show how the use of different data series can affect the results of analyses that depend on accurate estimates of China's livestock numbers. In this section, we demonstrate how alternative livestock series influence predictions of China's agricultural trade in the future. To do so, we use three alternative sets of data on meat—estimated by CNSB; F. Fuller, D. Hayes, and D. Smith; and the authors of this article—to predict China's cereal trade through 2010. The differences among the predictions will show the importance of having accurate information on the number of animals and the production of meat and eggs that come from them.

Three sets of predictions on the free trade model are run using the CAPSiM model—one using CNSB livestock numbers, one using those in Fuller, Hayes, and Smith,[42] and one using those created in this article (henceforth, CCAP).[43] In addition to the basic assumptions in the baseline model (which were designed to simulate China's economy prior to the nation's accession to the WTO), we simulate China's trade regime if all trade restrictions were removed. The only difference among the three sets of comparative forecasts are the different levels of meat and feed grain demands that are in the base year. Starting from these base year initial conditions and using the assumptions under a free trade scenario, we predict supply and demand for China's main crop and meat commodities. We generate net import forecasts for all commodities by taking the gap between consumption and production.

There are large differences in simulated agricultural trade forecasts among the three sets of comparisons (table 9). According to predictions made when the initial livestock production holdings are those generated by CNSB, China's imports will surge to 73.5 million metric tons in 2005 and continue to rise to 98.7 million metric tons in 2010. The large livestock herd size implied by the official national statistics could only be fed by a sharp rise in grain imports.

In contrast, if the figures of Fuller, Hayes, and Smith were used,[44] China would be exporting grain in every year between 2005 and 2010. The livestock production figures reported in Fuller, Hayes, and Smith are more than 30% lower than those reported in this article. The lower herd size numbers, however, would imply that under the baseline assumptions, China's producers could produce more than enough feed to supply all of its livestock throughout the next 10 years. Finally, when we use our supply predictions, imports rise under a free trade scenario. With our animal herd size used as a baseline, the CAPSiM model predicts that under free trade, importers will bring in 24.2 million metric tons in 2005, a reasonable amount of imports, given that China's tariff rate quota for major grains will be between 20 and 30 million metric tons in 2004. By 2010, imports rise to 44.1 but are still substantially under (less than half) the predictions that are derived when using CNSB statistics. In other words, because of the importance of livestock in China's future import regime, differences in initial levels of livestock make large differences in grain supply, demand, and trade predictions.

There are also significant differences in grain trade patterns because of different livestock production estimates. Since maize is major feed grain source, the levels of livestock production estimates will play an important role in determining future maize trade. Hence, the higher the livestock production estimates, the higher the projected maize imports. In the cases of CNSB and CCAP's data sets, China is forecast to import maize. The figures of Fuller, Hayes, and Smith, however, suggest that China will be able to export maize through 2007.

VII. Conclusions

In this article, we first demonstrate that China's livestock supply and demand statistics are not consistent with even the most basic criteria: that supply equal demand; that the implied derived demand for feed equal the supply of feed; and that the series be somewhat intuitive. We then use a number of data sources to create new supply and demand series. After correcting demand upward to make up for three omissions in the data, we correct supply down. The changes, which are all carefully documented, narrow the gap for all livestock products. The adjusted supply and demand series also meet the other criteria. A decomposition analysis shows that the single largest source of the discrepancy was the adjustment to supply and the adjustment to demand to account for the out-of-home consumption that CNSB's survey failed to account for.

If our adjusted data sets are correct, there are implications for the validity of past statistics and the accuracy of alternative forecasts. We have shown how differences in livestock statistical series can create such great discrepancies in predicted feed grain imports that some analysts believe China will export feed grain for the next 5 years or more, while others predict that the nation may import over 80 million metric tons. Meat trade would be subject to similar differences in forecasts. Beyond supply, demand, and trade, gross

domestic product (GDP) figures could be significantly influenced. Since livestock makes up 30% of agricultural GDP (AGDP), and since the growth rate of livestock was overstated by 37%, the reported growth rate of AGDP (which, according to CNSB, was 4% annually between 1987 and 1999) would have to be lowered by one percentage point to 3% annually. Gross domestic product growth would have to be lowered by 0.11%.

Making corrections to China's livestock statistics, however, may not be the end of the story. L. Li and H. Liu show that fishery statistics are subject to similar statistical problems.[45] H. Zheng says that township and village enterprise output and employment statistics were overstated.[46] All of these would support the recent findings by T. Rawski that China's overall growth data are overestimated.[47]

In short, as China develops and as the correlates of growth move in a direction that forecasts continued future growth, there will be a continuing and rising demand for higher quality data. Clearly, some of the data sets—the livestock data, in particular—are so poor that without adjustments it is impossible to have a firm base for investment and policy planning. Especially in an economy that is changing so fast and will continue to do so in the future, the challenge to improve data collection is more important now than ever.

Notes

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1. Margaret Grosh and Paul Glewwe, "Designing Household Survey Questionnaires for Developing Countries: Lessons from 15 Years of the Living Standards Measurement Study," working paper (World Bank, Washington, D.C., 2000).

2. Jikun Huang and Scott Rozelle, "Market Development and Food Demand in Rural China," *China Economic Review* 9 (1998): 25–45.

3. Frank Fuller, Dermot Hayes, and Darnell Smith, "Reconciling Chinese Meat Production and Consumption Data," *Economic Development and Cultural Change* 49 (2000): 23–43; Economic Research Service, "Statistical Revision Significantly Alter China's Livestock PS&D," in *Livestock and Poultry: World Market and Trade*, Circular Series FL&P 2-98 (Washington, D.C.: Foreign Agricultural Service, U.S. Department of Agriculture, 1998).

4. Food and Agricultural Policy Research Institute, "World Agricultural Outlook," Staff Working Report 2-99 (Food and Agricultural Policy Research Institute, Ames, Iowa, 1999); Interagency Agricultural Projections Committee, World Census of Agriculture, and Food and Agriculture Organization, "Agricultural Baseline Projections to 2008," Working Report no. 991 (U.S. Department of Agriculture, Washington, D.C., 1999).

5. Food and Agricultural Organization, "Agricultural World Census Program," report (Food and Agricultural Organization, Statistics Division, Rome, 2000; available online at http://www.fao.org/waicent/faoinfo/economic/ess/census/default.asp).

6. Funing Zhong, "Exaggeration and Causes of Meat Production Statistics Overreporting in China," *Chinese Rural Economy* (October 1997): 63–66.

7. The first step in creating the estimates involves choosing feed to meat con-

version coefficients. Second, we assume that the feed-meat conversion coefficient is declining over time due to technology progress in the livestock sector. The coefficient is consistent with the grain consumption of per unit of live hog (chicken, etc.) based on China's Cost and Return of Agricultural Production Survey. See table 1 for the conversion coefficients. Third, we assume that feed use that is not included in our study accounts for 10% of aggregate feed consumption. Though our study includes major animals that are used for meat production (swine, poultry, beef cattle, sheep, and goats), there are still some animals that are used either in dairy farms (cows) or as agricultural draft (horses, mules). Like Fuller, Hayes, and Smith, we assume this part of feed accounts for approximately 10% of total feed consumption.

8. Jikun Huang, Jun Song, Fanbin Qiao, and Keith O. Fuglie, *Sweetpotato in China: Economic Aspects and Utilization in Pig Production* (Bogor, Indonesia: International Potato Center, 2003). After calculating annual food and feed grains available in the economy for consumption use, we approximate estimated feed supply figures primarily from the corn, wheat bran, and sweet potato series. We assume that all corn and sweet potato is available for feed. Ten percent of the wheat production (and imports), which is assumed to be mostly the bran after milling, is supposed to be used for feed.

9. Shenggen Fan and Mercedita Agcaoili-Sombilla, "Why Projection on China's Future Food Supply and Demand Differ," *Australian Journal of Agricultural and Resource Economics* 41 (1997): 169–90; Jikun Huang, Scott Rozelle, and Mark W. Rosegrant, "China's Food Economy to the Twenty-first Century: Supply, Demand, and Trade," *Economic Development and Cultural Change* 47 (1999): 737–66.

10. For example, a recent survey (henceforth the Rural China 2000 Survey), run by a team made up of the Center for Chinese Agricultural Policy of the Chinese Academy of Sciences, the Department of Agricultural and Resource Economics of the University of California, Davis, and the Department of Economics of the University of Toronto, covered six provinces (Hebei, Shanaxi, Liaoning, Zhejiang, Sichuan, and Hubei) and 1,199 rural households. In this survey, we asked farmers about changes in the number of hogs that they slaughtered between 1990 and 2000. We found that while 10.4% of the households who engaged in hog raising during the last decade increased their herd size, 18.4% decreased. The number of slaughtered hogs per household rose but slightly from 0.96 in 1990 to 1.01 in 2000. Coupled with the expansion of commercial operations (thought to have expanded by about 63%), our estimates of hog production expansion that are based on in-field observations fall far short of CNSB's production figures. Based on the Rural China 2000 Survey, among 677 households that raised hogs, 2.5% are specialized or commercial operations (more than eight hogs) in 1990, and this percentage reached 4.1% in 2000. It means that commercial enterprises expanded 63% during the 1990s.

11. China Catering Industry Yearbook Agency, *China Catering Industry Yearbook* [Zhongguo Yinshiye Tongji Nianjian] (Beijing: China Catering Industry Yearbook Agency, 1992, 1999).

12. Jikun Huang and Howarth Bouis, "Structural Changes in the Demand for Food in Asia," Food, Agriculture, and the Environment Discussion Paper 11 (International Food Policy Research Institute, Washington, D.C., 1996).

13. Fuller, Hayes, and Smith; Zhong.

14. Food and Agriculture Organization of the United Nations, "Program Evaluation Report 1992–1993," available online at http://www.fao.org/pbe/pbee/docs/per/en/per9293E2-00.htm#P6_162; Gerhard Heilig, "Can China Feed Itself—a System for Evaluation of Policy Options," working report (International Institute for Applied System Analysis, Laxenburg, Austria, 1999).

15. Fang Cheng, Eric Wailes, and Gail Cramer, "China's Rural and Urban Household Survey Data: Collection, Availability, and Problems," Working Paper no. 98-WP 202 (Center for Agricultural and Rural Development, Iowa State University, 1998).

16. Food and Agricultural Organization, "Agricultural World Census Program" (n. 5 above).

17. Jointly run by enumeration teams from the Center for Chinese Agricultural Policy of the Chinese Academy of Sciences and the Center for Agricultural and Rural Development of Iowa State University, the survey covered 250 urban households in five cities, Chengdu (Sichuan Province), Jiangjin (Chongqing Municipality), Changchun (Jilin Province), and Weifang and Feixin (Shandong Province). The information was asked on a 1-week recall basis.

18. Alan de Brauw, J. Edward Taylor, and Scott Rozelle, "Migration and Income in Source Communities: A New Economics of Migration Perspectives from China," working paper (Department of Agricultural and Resource Economics, University of California, Davis, 2001).

19. Huang and Bouis.

20. Zhong.

21. Hengyun Ma, Jikun Huang, and Scott Rozelle, "Consumption of Food away from Home in China—a Case Study of Urban Consumers" (in Chinese), *Chinese Rural Economy* 3 (2001): 25–32.

22. We actually have to make one more adjustment to the consumption data between 1980 and 1984. Before 1985, CNSB's urban household study did not include urban households that lived in county-level towns or below. Implicitly, if one were to take per capita consumption levels from CNSB surveys and multiply them by the urban population, the figure would be assuming that the consumption patterns in small county-level cities are the same as those of larger metropolises. In fact, from our own survey, we know that this is not true. Consumers in county-level towns consume only about 67% as much meat as residents in larger cities. Using population data of both larger and midsize cities and county towns from the 1982 and 1990 national population censuses, we are able to estimate the proportion of the population that resides in these different areas. We then are able to adjust the total urban meat consumption for the part of meat consumed by those consumers in smaller towns.

23. De Brauw, Taylor, and Rozelle.

24. Huang and Rozelle (n. 2 above).

25. Huang and Bouis.

26. Xueguo Yuan, Jimin Wang, and Qing Han, "Were Chinese Livestock Statistics Inflated?" (in Chinese), *Chinese Rural Economy* 1 (2001): 48–54.

27. Actually, it is a widespread finding that for certain commodities, the estimate from the household survey falls short of the known consumption total calculated from data on production, imports, exports, and excise duties. For example, in the British Family Expenditure Survey, total tobacco expenditure was underestimated in 1976 by 21%. See Angus Deaton and Margaret Irish, "Statistical Model for Zero Expenditure in Household Budgets," *Journal of Public Economics* 23 (1984): 59–80.

28. Jin Chen, "Economic Development and the Evolution of Backyard Livestock Production: A Case Study of Hog Production in China" (Ph.D. diss., Department of Agricultural and Resource Economics, University of California, Davis, 2002).

29. Throughout our analysis, when we refer to the Ag Census, we use national numbers that are sums of the figures from China's 31 provinces and province-level municipalities (without Taiwan). For example, pork production based on the sum of provincial Ag Census pork production figures in 1997 was 28.6 million metric tons. For some reason, when CNSB uses the Ag Census data, they use numbers that they claim are national numbers that differ from those based on the sum of provincial figures. In the case of pork production, for example, their national figure is 31.6 million metric tons, 10% above that reported by the provinces. Since we have no reason to believe that provinces would purposely underreport their Ag Census data on livestock production, in this article we use the information that is based on the sum of provincial Ag Census data.

30. See apps. 2–3 in Hengyun Ma, Jikun Huang, and Scott Rozelle, "Reassessing China's Livestock Statistics: Analyzing the Discrepancies and Creating New Data Series," working paper (Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing, and Department of Agricultural and Resource Economics, University of California, Davis, 2002). This article can be found online at http://www.agecon.ucdavis.edu/facultypages/rozelle/publications/supplydemandtrade.htm.

31. Ibid., app. 2, cols. 7–8, for poultry, apps. 8–9 for eggs, and apps. 12–13 for beef and mutton.

32. Ibid., app. 4, col. 6.

33. Ibid., col. 5.

34. Ibid., col. 3.

35. Ibid., cols. 8–9 for poultry, and apps. 8, 13 for other animal products.

36. In this section, whenever we report growth rates from 1987 to 1998, we are using 3-year averages centered on these years. In other words, we compare the average of 1986–88 to 1997–99.

37. Ma, Huang, and Rozelle, "Reassessing China's Livestock Statistics: Analyzing the Discrepancies and Creating New Data Series," apps. 7, 10–11.

38. Ibid., apps. 5, 8.

39. Ibid., app. 5, col. 6.

40. Ibid., appendix fig. 2.

41. Ibid., fig. 1.

42. Fuller, Hayes, and Smith (n. 3 above).

43. For a complete description of the CAPSiM, see Huang, Rozelle, and Rosegrant (n. 9 above).

44. Fuller, Hayes, and Smith.

45. Luping Li and Haomiao Liu, "Recent Development in China's Fishery Economy: Reassessment of Statistics for Production and Consumption," working report (Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing, 2002).

46. Han Zheng, "A Study on the Statistical Error of the Number of Employees Working in Collectively Owned Township and Village Enterprises" (Master's thesis, Center for Chinese Agricultural Policy, Chinese Academy of Sciences, Beijing, 2001).

47. Thomas Rawski, "What Is Happening to China's GDP Statistics?" *China Economic Review* 12 (2001): 347–54.