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Suggested citation format:

Young, R. E. II, and G. M. Adams. 1992. "Analysis of the Changing Structure of U.S. Feed Demand." Proceedings of the NCR-134 Conference on Applied Commodity Price Analysis, Forecasting, and Market Risk Management. Chicago, IL. [http://www.farmdoc.uiuc.edu/nccc134].

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Robert E. Young II and Gary M. Adams[1]

Introduction

More acres are used in the production of corn for feed than any other single grain, oilseed or fiber crop planted in the United States. Feed use of corn is the largest single demand component of all grains, oilseeds and fibers produced in the United States when taken on an acreage basis. In the 1990 crop year, the value of corn fed on and off the farm exceeded $10 billion. Feed use under went a marked increase in the 1950s. In 1950, corn feed use totaled 2,482 million bushels. By 1969, corn feed use approached 4,700 million bushels. Since 1970 the rate of increase in corn feed use has slowed. By the 1975 crop year feed use was down to 3,581 million bushels. In 1987 feed use recovered again reaching 4,798 million bushels and is expected to approach 5,000 million bushels in 1991 (USDA-various).

During this time the makeup of the livestock industry has also undergone substantial changes. The rise of the poultry industry, and the weakening of demand in the beef sector are two dominant factors. Also of significant concern have been improved technologies with respect to the feeding of animals. One measure of this change was referred to by Adams and Brown (1991). They discuss changing corn feed requirements and refer to feed recommendations made by the National Academy of Sciences.

The research question asked by this paper is: Has the own-price elasticity of feed demand of corn changed? Stated as a hypothesis, the null would be - the own price elasticity of corn feed demand has not changed over time.

Economic Theory

Corn feed demand is solidly nested in economic theory. Feed use is essentially a derived demand, with corn being one of the inputs into the production of livestock and livestock products. Consider the aggregate production of livestock to be measured by Q_L, where Q_L is an aggregate quantity of meat, milk, eggs and other livestock output. To produce these aggregate outputs, further assume that three inputs are required: corn, soybean meal and young or feeder animals. In the aggregate, use of these inputs are given by Q_C, Q_M and Q_F respectively, and the livestock production function is given by $Q_L = F(Q_C, Q_M, Q_F)$.

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One technique is to assume that for any given time period the quantity of young animals is fixed. Given biological lags in the cattle sector, this assumption may be valid. For other livestock components such as broilers, this may not be appropriate, but for now, assume Q_F is fixed at Q^*_F. The profit function for a producer in this case becomes:

$$(1)\ \pi = P_L \times Q_L - P_C \times Q_C - P_M \times Q_M - P_F \times Q_F$$

where P_L = price measure of livestock productions
P_C = price of corn
P_M = price of soybean meal
P_F = price of animals to be fed

With Q_F fixed at Q^*_F, the producers goal is to maximize profits by selecting appropriate levels of Q_C, Q_M, and Q_L.

Taking the partial differentials of (1) with respect to Q_C and Q_M and setting the differentials equal to zero gives

$$(2)\ \frac{\partial \pi}{\partial Q_C} = P_L \times F_1\ (Q_C\ ,Q_M\ ,Q_F^*) - P_C = 0$$

$$(3) \frac{\partial \Pi}{\partial Q_M} = P_L \times F_2\ (Q_C\ ,Q_M\ ,Q_F^*) - P_M = 0$$

where

$$F_1(\,) = \frac{\partial Q_L}{\partial Q_C} \qquad F_2(\,) = \frac{\partial Q_L}{\partial Q_M}\ .$$

Solving equations (2) and (3) for Q_C and Q_M gives

$$(4)\ Q_C = g_1\ (\ P_C\ ,P_M\ ,Q_F^*\ ,P_L\ )\ .$$

Thus, the derived demand for corn feed use is a function of the price of corn (P_C), the price of meal (P_M), the fixed number of animals to be fed (Q^*_F), and the price of the finished, or fed, livestock unit (P_L). The signs on each of these terms would then be -, +, +, +, with the positive sign on the price of soybean meal implying complements with corn.

A specification of this type has been used by numerous other authors. Previous studies include Womack (1976) and Perso, et al (1987).

Corn Feed Demand - A Simple Approach

The question of changing demand for corn feed use can be examined in a number of different ways. Estimates of the equation in a log-log functional form from 1950 to 1970 and from 1971 to 1990 are given in Table 1. In a log-log functional form, elasticity estimates are given by the coefficients. Thus the price elasticity with respect to corn price fell from -0.60 in the 1950-1970 time period to -0.22 in the 1971-1990 period. Similarly, the price elasticity for soymeal prices also declined markedly.

Table 1
Corn Feed Demand Elasticities
Log-Log Functional Form

Time Period	1950-1970	1971-1990[1]
P_{corn}	-0.60	-0.22
	(0.07)	(0.06)
P_{meal}	0.30	0.15
	(0.07)	(0.09)
GCAU-USDA*	1.65	1.48
	(0.27)	(0.40)

* - Grain Consuming Animal Units - developed and reported by USDA.
1) Equation estimated from 1971 to 1990 included dummy variables for 1976, 1977 and 1988.

There is at least one feature of both estimated equations which causes some concern. The elasticity with respect to grain consuming animal units is greater than 1 in both cases. In other words, an increase in an aggregate measure of animal units of 1 percent increases feed use of corn by more than 1 percent. This result is not intuitive as it implies increasing feeding rates per animal unit as the herd is increasing in size and just the opposite as animal numbers are falling.

The equation could also be estimated using a linear functional form. When estimating a demand equation in linear form, it is recognized that the elasticity estimates will change with the level of demand, and it is also recognized that confidence intervals are not simply given by the standard errors of the parameter estimates. Miller, Capps and Wells (1984) provide a methodology for estimating exact confidence intervals for linear forms.

Table 2 provides the elasticity estimates for linear specifications similar to that laid out in Table 1. Elasticities are estimated at the mean. Exact 95% confidence intervals for the elasticities are provided. Clearly, between the 1950 - 1970 and the 1971 - 1990 periods, the elasticity decreased. While overlap does occur in the range estimates, the 1971 - 1990 period is well toward the low end of the 1950 - 1970 estimate. Thus, there is substantial amount of statistical evidence to suggest a change in the elasticities, even without the constant elasticity restriction imposed by the log-log form.

Table 2
Corn Feed Demand Elasticities
Linear Functional Form

Time Period	1950 - 1970[1]	1971 - 1990[2]
P_{CORN}	-0.52 (-0.13 to -0.92)	-0.23 (-0.10 to -0.36)
P_{MEAL}	0.21 (0.06 to 0.36)	0.08 (-0.06 to 0.22)
GCAU-USDA	1.85 (1.32 to 2.36)	1.29 (0.41 to 2.13)

1) Equation estimated with dummy variable for 1950.
2) Equation estimated with dummy variables for 1971, 1972 and 1976 and 1977.

It is also interesting to note the elasticities given from the animal unit parameter. For the 50 - 70 period, the 95% confidence interval ranges from 1.32 to 2.36. For the 71 - 90 period, the interval ranges from 0.41 to 2.13. This again is somewhat counter-initiative, especially the upper ranges of the intervals.

As mentioned earlier, the elasticity estimate will change at all points on the demand curve in a linear specification. Thus elasticities can be estimated for each observation. Estimating demand over the entire 40 year period and calculating the associated elasticities gives Figure 1. Note that ϵ_{PC} moves from a relatively high absolute value of 0.8 to around 0.3 by the early 1970's. The increase in the magnitude of ϵ_{PC} in 1973, 1974 and 1975 is during the price control period, and immediately after.

FIG. 1 CORN FEED DEMAND ELASTICITIES

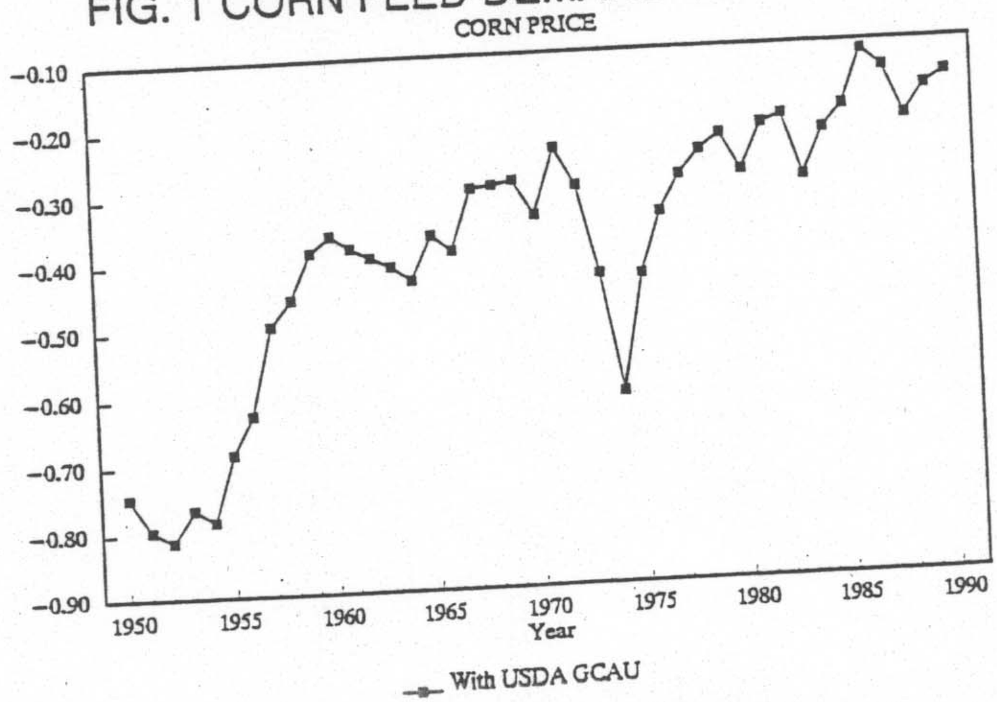
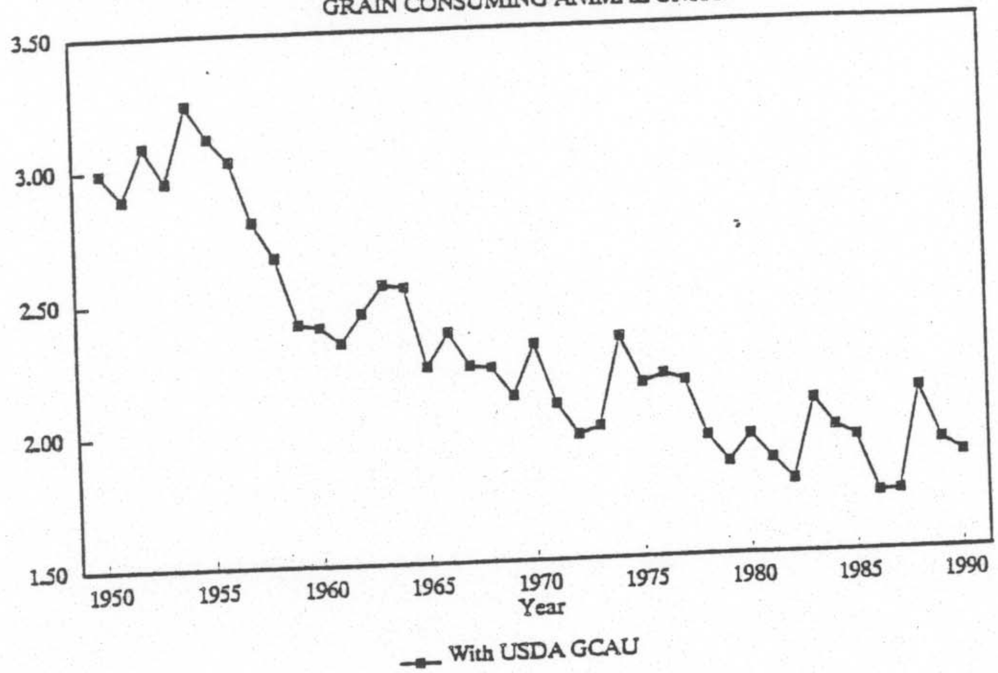


FIG. 2 CORN FEED DEMAND ELASTICITIES

GRAIN CONSUMING ANIMAL UNITS



In general, ϵ_{PC} can be seen to decrease, in absolute value terms, markedly during the 1950's and continuing to decline at a somewhat slower rate ever since. Figure 2 provides the same elasticity calculation, but in this case with respect to GCAU. Note a somewhat similar pattern, but in the opposite direction from 1960 forward. Again, it is recognized that ϵ_{GCAU} remains close to 2.0.

Alternative Grain Consuming Animal Units

The concern regarding the responsiveness of feed demand with respect to a measure of grain consuming animal units has also been expressed by Adams and Brown (1991). The GCAU measure used in the previous section is that developed and reported by USDA. This measure aggregates animals into one unit, using a dairy cow as the basis of measure. A dairy cow is assumed to consume 4293 pounds of feed on a corn equivalent basis, with a broiler consuming 9.2 pounds. Thus 466.6 broilers are equivalent to one dairy cow.

The GCAU developed by USDA fixes these weights at the levels indicated. Adams and Brown, utilizing feeding recommendations developed by the National Academy of Sciences have reaggregated animals into a new animal unit. This aggregate measure adjusts through time as feeding technology changes. The biggest area of difference comes in the feeder cattle area. Under USDA weighting, cattle in a feedlot consume 77% of grain consumed by a dairy cow on a corn equivalent basis. Under the Adams-Brown scheme a feeder consumes 98% of a dairy cow ration. The cause is due more to a decrease in dairy cow feed requirements than to an increase in feeder cattle consumption needs. This is particularly important for measuring the effects of the poultry industry. As mentioned earlier, USDA's measure requires 466 broilers to equal 1 dairy cow. Under the Adams-Brown measure, 354 broilers in 1969-1971 were equivalent to 1 dairy cow. The derivation of the new GCAU measure is described in the appendix.

Use of Alternative Grain Consuming Animal Unit

Table 3 provides a comparison of elasticity estimates for corn feed use using the Adams/Brown GCAU derivation. For data limitation reasons, the Adams/Brown GCAU measure is only available from 1961 through 1990. Thus a sufficient number of degrees of freedom do not exist to estimate two separate time periods utilizing the Adams/Brown GCAU.

A significant point given in Table 3 is the robustness around the parameter for GCAU, irrespective of the functional form. In fact, all elasticities using the Adams/Brown GCAU are very similar, and have an elasticity close to 1. Finally, elasticities with the Adams/Brown GCAU figure to be much more stable over time than the USDA GCAU. Either the linear or the log-log specification utilizing the Adams/Brown GCAU estimate probably merits attention when developing models of the U.S. feed grain sector.

FIG. 3 CORN FEED DEMAND ELASTICITIES

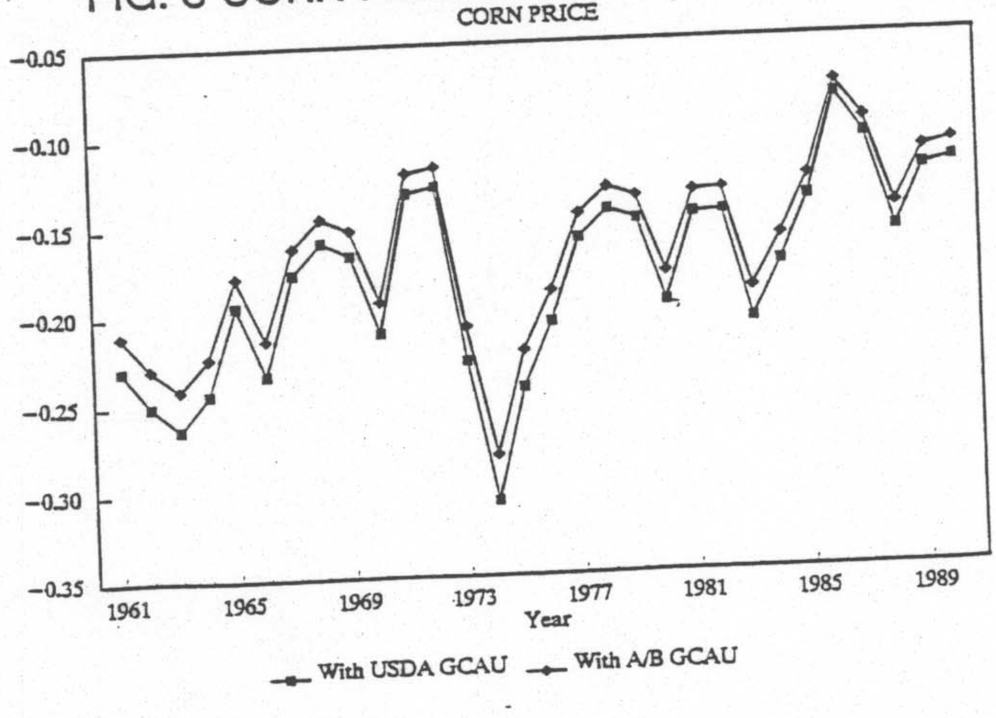


Table 3
Corn Feed Demand Elasticities

	1961-1990 USDA GCAU	**1961-1990** Adams/Brown GCAU
Log-Log Functional Form		
P_{CORN}	-0.19	-0.16
(S.E.)	(0.07)	(0.05)
P_{MEAL}	0.04	0.10
(S.E.)	(0.08)	(0.05)
GCAU	2.70	1.04
(S.E.)	(0.36)	(0.09)
Linear Functional Form		
P_{CORN}	-0.17	-0.16
(95% C.I.)	(-0.03 to-0.32)	(-0.04 to-0.28)
P_{MEAL}	0.06	0.10
(95% C.I.)	(0.21 to-0.09)	(-0.01 to 0.20)
GCAU	2.73	1.04
(95% C.I.)	(1.90 to 3.61)	(0.82 to 1.28)

Longer Term Implications and Conclusion

Irrespective of the GCAU specification and irrespective of the functional form, th in corn feed demand elasticities is toward smaller absolute values. Figure 3 shows the elasticity calculation using both the USDA and Adams/Brown GCAU terms. While consi variation exists, particularly in the mid 1970's, the general trend toward higher deg inelasticity is apparent. In 1969, ϵ_{PC} was -0.18 to -0.15. In 1988 it was close to -0.10

This is not surprising or revealing given the nature of corn feed use and the specifi chosen. For a linear, inelastic demand curve, the elasticity must get smaller as one m higher levels of demand. It is likely that this is exactly what is shown in this analy structural change probably occurred in the 1950's as is shown by Figure 2. During th the ϵ_{PC} changed rapidly, declining almost every year. From the early 1960s through 1 change has been relatively minor, with the exception of the mid 1970s.

The initial research question posed by this paper was: Has the elasticity of de corn with respect to the price of corn changed? After examination of two functional fo examination of an alternative to an aggregate livestock measure a null hypothesis elasticity has not changed in the past 15 to 20 years cannot be rejected.

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Appendix
Development of Aggregate Livestock Production

The theoretical specification of the derived demand for corn feed use necessitates the construction of total production(Q_L) which will aggregate the different livestock classes (beef, pork, poultry, eggs, and dairy). To clearly present the proper construction of Q_L, the following assumptions are made: (1) each livestock class is homogenous with respect to feed (corn) efficiency, (2) feed efficiency remains constant over time for each livestock class, and (3) the reported annual production level for each livestock class is the appropriate level of output for that class. Each of these assumptions is made at this point only to allow a precise development of Q_L. These assumptions are unrealistic and will be relaxed in subsequent development.

From the assumptions above, Q_L becomes

$$Q_{Lt} = a \times \sum_{i=1}^{n} PROD_{it} ,$$

where a = units of corn per unit of livestock production,

$PROD_{it}$ = annual production units of the i^{th} livestock class in year t,

n = total number of livestock classes,

t = year.

In this most restrictive case, the production units could be summed together and used as the independent variable Q_L in the corn feed demand specification. The parameter estimate on this variable would be an estimate of a.

Relaxing the first assumption allows the amount of corn needed per unit of livestock production to vary among the different classes of livestock. Q_L now becomes

$$Q_{Lt} = \sum_{i=1}^{n} \left(\frac{a_i}{a^*} \times PROD_{it} \right) ,$$

where a_i = units of corn per unit of production of the i^{th} livestock class,

a^* = pounds of corn per unit of production of the base livestock class.

The ratio of a_i to a^* converts the production units of the i^{th} livestock class into equivalent production units of the base livestock class. The base livestock class can be any of the n livestock classes. It is therefore implied that the class used as the base becomes the aggregate reference class Q_L. Accordingly, the parameter estimate associated with Q_L is an estimate of the units of corn per production unit of the base livestock class.

Assuming that a_i is fixed over time implies that technology has remained constant. Although this second assumption is convenient, it is not an accurate representation of what has occurred over time in the different classes of livestock. Broiler production is just one example where feed efficiency has increased over time as new technologies have been applied. Allowing feed efficiency to vary over time leads to

$$Q_{Lt} = \sum_{i=1}^{n} \left(\frac{a_{it}}{a^*} \times PROD_{it} \right),$$

where a_{it} = units of corn per unit of production of the i^{th} livestock class in year t.

The variable a* is not allowed to vary over time. It is held constant so that Q_L represents the production of the base livestock class in terms of the base year. This implies that the parameter estimate on Q_L is an estimate of the units of corn needed per production unit of the base livestock class in the base year.

Using annual production levels for the dairy, poultry, and egg categories is reasonable since the length of time for production to occur is quite short; however, for beef and pork, the feeding period can last several months. The extended feeding period leads to annual production levels that are not representative of output that actually occurred in beef and pork. These sectors contain a significant portion of output in terms of changes in live animal inventories (assumption three). To overcome this problem, the final specification for Q_L is

$$Q_{Lt} = \sum_{i=1}^{n} \left(\frac{a_{it}}{a^*} \times PROD_{it} \right) + \sum_{j=1}^{m} \left(\frac{a_{jt}}{a^*} \times b_{jt} \times AN_{jt} \right),$$

where b_{jt} = average finished weight of the j^{th} livestock class in year t,

AN_{jt} = number of finished animals of the j^{th} livestock class produced in year t.

The first term in Q_L is the same as the previous specification and is the appropriate term to use for aggregating the dairy, poultry, and egg classes. The second term in Q_L is used to aggregate the beef and pork classes. In addition, the two terms are in the same units (units of production of the base livestock class in the base year) allowing them to be summed together to find an estimate for Q_L.

To clarify the second term in Q_L, it is noted that

$$AN_{jt} = \sum_{k=1}^{q} \left(\frac{C_{kjt}}{C_{jt}} \times (BINV_{kjt} - EINV_{kjt}) \right) + FAN_{jt},$$

where C_{kjt} = units of corn left to feed in year t before animals of the j^{th} livestock class and k^{th} weight group reach finished weight,

C_{jt} = units of corn needed in year t to feed an animal of the j^{th} livestock class from birth to a finished weight,

$BINV_{kjt}$ = beginning inventory of animals of the j^{th} livestock class and k^{th} weight group in year t,

$EINV_{kjt}$ = ending inventory of animals of the j^{th} livestock class and k^{th} weight group in year t,

FAN_{jt} = number of feeder animals of the j^{th} livestock class that will need C_{jt} units of corn in order to reach a finished weight,

q = number of weight groups.

Using pork as an example, pig crop figures would be representative of FAN since each pig will require C_{jt} units of corn before it will reach a finished weight. Market hog inventories by weight group relate to BINV and EINV. The ratio of C_{kjt} to C_{jt} is the percent of total corn needed to feed the k^{th} weight group to a finished weight. This allows the inventories to be aggregated with pig crop in a consistent manner. Multiplication of AN_{jt} by the average finished weight (b_{jt}) creates a proxy for output even though some of the output is not yet realized in the annual production figures.

Up to this point, Q_L is constructed only to capture the demand of feed for current production. However, there is an additional feed use that needs to be considered, i.e. the investment demand for feed. Livestock producers must carry breeding stock in order for future production to occur. In order to maintain the breeding stock, producers must feed certain levels of grain (corn). To account for this additional demand, the amount of corn needed to maintain the respective breeding herds is converted into an equivalent number of production units of the base livestock class in the base year that would have occurred. This amount of production is then added to Q_L. This approach seems reasonable given the relatively small portion of corn that is fed to breeding animals, yet to ignore this component would underestimate corn feed use.

Many other studies (Arzac and Wilkinson, Perso et al.) dealing with corn feed demand have used a series called grain consuming animal units (GCAU) in their empirical estimations. GCAU is a series constructed by the USDA which attempts to aggregate livestock classes in a manner similar to Q_L. Although the two series are on different units, they both attempt to measure aggregate livestock production. Upon closer inspection of the two series, several differences appear that merit further discussion.

One major difference between the two series is the derivation of weights used to represent feed efficiency (units of corn per unit of output). In the construction of Q_L, the amount of corn needed per unit of production is used whereas, in GCAU, the weight used is the amount of grain and concentrates needed per animal unit where all grains and concentrates have been converted into a corn equivalent amount. This weighting scheme causes GCAU to overestimate the amount of corn needed in response to changing animal numbers of any class since it does not isolate corn use per animal. In addition, the livestock classes that require a higher level of protein are overestimated more in percentage terms than the classes that require a lower level of protein. Table 1 shows a comparison of the feeding rates used in computing GCAU and Q_L.

Table 1. Feeding Rates used to Aggregate Livestock Classes[a]

	GCAU		Q_L	
	Pounds of Feed[b]	Percent of a Dairy Cow	Pounds of Corn	Percent of a Dairy Cow
Dairy Cows	4293	100	3183	100
Cattle in the Feedlot	3311	77	3117	98
Hogs Fed	1127	26	665	21
Broilers	9.2	.2	9	.3
Turkeys	92	2	42	1
Hens	94	2	66	2

[a] Based on the 1969-71 period. GCAU holds these feeding rates fixed over time while Q_L allows these to vary.
[b] Total feed consumed on a corn equivalent basis.

The largest discrepancy occurs in cattle in the feedlot. In GCAU, a beef feeder animal is only 77 percent of a dairy cow, while in Q_L, it is 98 percent of a dairy cow. This occurs due to the fact that in GCAU, animals on a higher protein ration get more weight than those on a lower protein ration.

Changes in feed efficiency over time are completely ignored in the calculation of GCAU, which is based on weights that were developed from feed consumption data over the 1969-71 period. Over twenty years later, these weights are still being used to calculate GCAU. USDA recognized that feeding rates change over time (SSB No. 530, 1974, p. 2), yet they have opted not to incorporate changes in feeding rates in their calculation of GCAU.

A third difference between the two series occurs in the beef component of the respective series. Q_L uses both cattle on feed at the beginning of the year and cattle placed on feed during the year. GCAU uses only cattle on feed at the beginning of the year. The weight used in GCAU is adjusted to account for cattle placed on feed during the year, but since this adjustment is held constant, it fails to capture changes in placements that occur over time.

Given the number of exclusions in the calculation of GCAU by the USDA, this study attempts to shed more light on the estimate of an aggregate livestock production unit. The production quantity Q_L developed in this paper provides a modified estimate for aggregate livestock production. The series constructed for Q_L, broken down by livestock class, is shown in Figure 2. Data used to construct Q_L is found in reports published by the National Academy of Sciences, Council of Animal Nutrition, as well as various USDA publications. Beef and pork continue to be the dominant classes in determining Q_L, but broiler's share has more than doubled over the 1961-89 period. Also dairy's share of Q_L continues to increase slightly over time despite declining dairy cow numbers.