Market Power and the Cattle Cycle

~forthcoming Amer.J. of Agr. Econ.~

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Abstract: The relationship between the dynamic cattle cycle and the potential for market power in cattle purchases has rarely been studied. This paper provides a conceptual framework showing how the cattle cycle and buyer market are related. Not only does a larger cattle stock lead to a lower fed cattle price, but the cattle stock's negative effect on price is magnified by the degree of buyer market power in cattle procurement. Empirical findings support the posited theoretical relationships and help explain why previous researchers reached different conclusions regarding the extent of market power in the industry.

Key words: cattle cycle, livestock procurement, market power.

Running head: Market power and the cattle cycle.

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The authors gratefully acknowledge the suggestions and critiques of two anonymous referees and Editor Dorfman. The authors also acknowledge the helpful comments of Michael Caputo, Kevin Dhuyvetter, Terry Kastens, Richard Porter, Richard Sexton and participants of the 2008 AAEA conference and the 2009 Risk & Profit conference at Kansas State University. All errors are ours. Crespi and Xia share senior authorship.

Background

While it is well known that cattle production follows a dynamic cycle, indeed, one that has often been analyzed and, while cattle markets have received much attention because of the potential for buyer market power, relationships between the two have been little studied. The interaction of the cattle cycle and buyer market power has significant welfare and policy implications for cattle producers, beef processors and marketers, consumers, and policymakers. How the oft-analyzed cattle cycle interacts with packers' market power in cattle procurement, affecting the bargaining position between cattle producers and beef packers is an important unanswered question. This paper provides a conceptual framework to study how the cattle cycle and buyer market power jointly affect the bargaining position of producers and packers. By conducting an empirical estimation using data from U.S. cattle markets, we then look for the implied effects of the conceptual model.

Historically, profitability factors have resulted in cyclical increases or decreases in U.S. cattle numbers. Other factors such as weather (long term droughts that impair forage supplies, for example) and herd health issues such as BSE events (both in the U.S. and globally) can enhance or magnify the supply and demand factors that drive the cattle inventory cycle. The interested reader is referred to Marsh (1994, 1999), Rosen, Murphy, and Scheinkman (1994) and Hamilton and Kastens (2000) for detail on the cycle itself.

This cattle cycle likely affects the bargaining position between producers and packers yet, so, too, does the industry's market structure. Beef packing has become increasingly concentrated in the United States (Ward 2002). From 1976 to 2007, the four-firm concentration ratio of U.S. steer and heifer slaughter increased from 25% to 80% (U.S. Department of Agriculture 2009; Ward 2002). Cattle producers and policy makers are concerned about the possible weakening bargaining power of cattle producers (McEowen, Carstensen and Harl 2002; Rogers 2002). Recently, producers and others urged the U.S. Department of Justice (DOJ) to reject JBS Beef's acquisition of both National Beef and Smithfield Beef, a move that would have given the top 3 beef packers a greater than 85% share of the procurement market. In October 2008, the DOJ responded that it would allow the acquisition of Smithfield but not of National. Surveys by Azzam and Anderson (1996) and Ward (2002) summarize much of the economic analysis of the price effect of beef packers' exercise of market power and the competitive implications of various forms of vertical coordination. However, no published research has established the link between production and purchasing decisions that affect the cattle cycle and any subsequent buyer market power in cattle procurement markets.

The effect of supply changes on market power have been put forward on occasion. Sexton and Zhang (1996) examined the effect of supply movements on market power in perishable commodity markets, specifically iceberg lettuce. The only paper that explicitly takes supply variance into account in an examination of market power in cattle markets is by Stiegert, Azzam and Brorsen (1993, hereafter SAB). While SAB do model the effect on market power from *anticipated* supply shocks where packers employ some average pricing cost, SAB's major contribution to the literature in their paper is the effect of *unanticipated* supply shocks on market power. SAB found that when supplies were unexpectedly low, packers competed for cattle very aggressively. By comparison, our paper complements the work of SAB by examining the joint effects of market power and the ebbs and flows of the cycle itself – ebbs and flows that, unlike in the previous paper, can be altered through optimizing decisions by the participants– as opposed to shocks.

[Table 1 about here.]

Part of the need for further study can be motivated by the conflicting results in the literature (table 1) where measured market power in cattle procurement has been found to be either small (e.g. Azzam 1997; Morrison Paul 2001) or more pronounced (Crespi and Sexton 2004, 2005). The conceptual model we develop lends insight into the plausible supposition that the time period of the cattle cycle where the measurements are taken can importantly affect the results. For example, Morrison Paul (2001) examined market power in the packing industry using firm-level, transaction-specific data from 1992-93. Crespi and Sexton (2005) used very similar firm-level, transaction-specific data covering 1995-96. Both data sets were obtained as the result of regulatory oversight and both papers were developed for the specific purpose of measuring market power in beef processing. Aside from the time difference, the only difference in the data gathered was that Morrison Paul (2001) had a national data set whereas Crespi and Sexton (2005) had a regional data set from the Texas Panhandle.

What is intriguing is that both papers came to quite different conclusions concerning market power. Morrison Paul (2001) concluded that there was little to no buyer market power as measured by an estimate of non-competitive markdown of the price packers paid for fed cattle. Crespi and Sexton (2005), however, found markdowns from 5-10%. The difference in results could be due to geographical differences or due to technique (Morrison Paul (2001) used a cost equation model whereas Crespi and Sexton (2005) used a bidding model), but timing suggests another possibility. Judging by cattle inventories, Morrison Paul (2001) appears to have been looking for market power during a seller's market, whereas Crespi and Sexton (2005) may have been looking for market power during a buyer's market. We are aware of no discussion in the cited literature suggesting that the differences in the measures of market power may be attributable to the swings of the cycle. The conceptual model that follows considers this question and provides additional insight.

The Conceptual Model

We begin the conceptual model by considering the objective function of cattle producers. To cut down on unnecessary parameterization, we integrate the cow-calf, ranching, and feedlot operations into a single sector called "cattle production." While packing operations are highly concentrated, feedlot and ranching operations as noted by many researchers are numerous (e.g. the summaries of previous work in Azzam and Anderson 1996; Morrison Paul 2001; Crespi and Sexton 2005). In keeping with the spirit of earlier studies examining packer buyer power over upstream operations, usually feedlots, the simplifying integration is justified in that the initial upstream production operations are competitive and atomistic: there is no benefit in separating out stages where marketing costs are arguably exogenous.

There are a large number, *M*, of cattle producers and each producer is a presumed price taker in a cattle procurement market. Following Rosen, Murphy, and Scheinkman (1994), we assume a one-year gestation for breeding stock and a two-year maturation lag for calves. After one year, each cow reserved for breeding will give birth to and wean λ calves; as not every cow will successfully wean a calf, the weaned calf expectation is $\lambda < 1$. After another two years, the λ calves-per-cow will become adult cattle. The natural death rate for cattle during the production stage is $\delta \in (0, 1)$. After one year, $1-\delta$ of the cattle reserved for breeding would survive. Thus, the adult stock s_t of an individual producer in period *t* can be expressed as

(1) $s_t = (1-\delta)x_{t-1} + \lambda x_{t-3}$,

where x_{t-1} and x_{t-3} are the breeding stocks chosen by the producer in time periods $t-1$ and $t-3$, respectively. Notice that we are focusing in equation (1) on the portion of supply that arises through previous decisions by the producer (Hamilton and Kastens 2000) as opposed to shocks (Stiegert, Azzam and Brorsen 1993), because we are interested specifically in the impact of producer and processor behavior on the cattle stocks as opposed to the effect of the shocks on the cattle supply.

The quantities of cattle are measured in generic units in this model, but the choice of units (heads, pounds, cwt) is innocuous as we presume a constant yield per animal for simplicity so that quantities can be translated between units with an appropriate choice of the transformation parameter resulting in the yield.

At time period t, each producer chooses to keep x_t female cattle in the breeding stock and sell the remaining adult cattle,

(2) $q_t = s_t - x_t$,

to beef packers at a price of P_t per unit. At period t, the cost of maintaining a feeding stock x_t is $(1/2) g_t x_t^2$, where $g_t > 0$. The per-unit variable cost for a producer's entire cattle herd, which consists of s_t adult cattle and λx_{t-2} calves, is $h_t > 0$. Thus, a producer's profit in time period *t* is

(3) $\pi_t = P_t q_t - (1/2) g_t x_t^2 - h_t (s_t + \lambda x_{t-2})$.

Substituting equations (1) and (2) into (3), we obtain

(3') $\pi_t = P_t ((1-\delta)x_{t-1} + \lambda x_{t-3} - x_t) - (1/2) g_t x_t^2 - h_t ((1-\delta)x_{t-1} + \lambda x_{t-2} + \lambda x_{t-3})$.

Because a producer's choice of breeding stock in one period can affect his profit in both the current and future periods, a producer's optimization problem is

(4) $\max_{\{x_t\}} \Omega_t = \pi_t + E_t\left(\sum_{j=1}^{\infty}(1+r)^{-j}\pi_{t+j}\right),$

where Ω_t is the present value of a producer's current profit and expected profits in future periods, $E_t(\cdot)$ is the expected value at time period *t* for variables at time period *t* + *j*, and *r* is the discount factor. Substituting (3') into (4) and solving the first-order condition yields an individual producer's optimal choice of breeding stock,

(5) $x_t = -P_t/g_t + W_t/g_t - C_t/g_t$,

where

$$W_t = \left[(1-\delta)/(1+r)\right]E_t(P_{t+1}) + \left[\lambda/(1+r)^3\right]E_t(P_{t+3})$$

is a function of the present values of expected cattle prices and

$$C_t = \left[(1-\delta)/(1+r)\right]E_t(h_{t+1}) + \left[\lambda/(1+r)^2\right]E_t(h_{t+2}) + \left[\lambda/(1+r)^3\right]E_t(h_{t+3})$$

is a function of the present values of expected variable production costs. The optimal breeding stock of cattle is decreasing in the current fed cattle price and the cost of future production, while increasing in the expected fed cattle price in periods $t+1$ and $t+3$.

Substituting (5) into (2) yields an individual producer's supply function of cattle for slaughter. By multiplying the individual supply by the number of producers *M*, we obtain the market supply function of cattle for slaughter,

(6) $Q_t = f(P_t) = (M/g_t)P_t + S_t - (M/g_t)W_t + (M/g_t)C_t$,

where $Q_t = Mq_t$ and $S_t = Ms_t$ are the market supply of cattle for slaughter and the adult cattle stock of the entire market, respectively.

Next we consider the beef packers' decisions. At time period *t*, $N_t \geq 1$ beef packing firms purchase cattle from producers in this cattle procurement market, process them, and sell packaged beef at a price V_t in a competitive beef market. In this conceptual model, we assert that N_t affects the degree of buyer market power in cattle procurement markets. Smaller values of N_t represent stronger buyer market power. While it is true that concentration is high among packers in the United States, selling markets are national and international in scope while purchasing markets are regional. Hence the assumption that there is potential market power in the purchasing of cattle, but little in the selling of boxed beef is reasonable. It also conforms to previous research (e.g. Morrison Paul 2001). Assuming constant unit variable processing and selling cost k_t, the per-unit gross profit of beef processing is $R_t = V_t - k_t$. Packer *i* (*i* = 1, 2, …, N_t) procures and processes $q_{i,t}$ cattle and $\sum_{i=1}^{N} q_{i,t} = Q_t$. Thus, packer *i*'s profit in time period *t* is

(7) $\Pi_{i,t} = \left(R_t - P_t\right) q_{i,t}$.

We assume quantity (Cournot-Nash) competition between beef packers in the cattle procurement market. A packer knows that its quantity choice q_{it} at time period *t* affects not only her current profit, but also the market's breeding stock $S_t - Q_t$, which then affects cattle stocks in future periods and, in turn, her future profits. Thus, this dynamic interaction between the procurement for slaughter in the current period and adult cattle stocks in future periods affects a packer's current purchase decision. Letting X_t denote the entire breeding stock of the market at time period *t*: $X_t = S_t - Q_t$ and using equation (1), we can express the entire adult cattle stock in the market at time period *t* as

(8) $$\begin{aligned} S_t &= \left(1-\delta\right) X_{t-1} + \lambda X_{t-3} \\ &= \left(1-\delta\right)\left(S_{t-1} - Q_{t-1}\right) + \lambda\left(S_{t-3} - Q_{t-3}\right). \end{aligned}$$

Equation (8) shows that the current adult cattle stock depends on previous breeding stocks, which, in turn, depend on the previous cattle procurements for slaughter and adult cattle stocks.

Substituting (8) into (6), solving (6) for P_t, and substituting the solution into (7) yields

(7') $\Pi_{i,t} = \left\{ R_t + \left[(1-\delta)(S_{t-1} - Q_{t-1}) + \lambda (S_{t-3} - Q_{t-3}) - Q_t \right] (g_t / M) - W_t + C_t \right\} q_{i,t}$.

Because a packer's current quantity choice affects her profit from both current and future periods, packer *i*'s profit maximization problem in time period *t* is

(9) $\max_{\{q_{i,t}\}} \Psi_{i,t} = \Pi_{i,t} + E_t \left(\sum_{j=1}^{\infty} (1+r)^{-j} \, \Pi_{i,t+j} \right)$,

where $\Psi_{i,t}$ is the present value of packer *i*'s current and expected profits. At time period *t*, the cattle stock S_t is predetermined and non-stochastic. S_t is predetermined because it depends on the breeding, stocking, and procurement decisions in the previous periods as given by equation (8). In this analysis, we have removed random shocks of the cattle stock, S_t , at time period *t* to focus on the role of producers' and packers' previous production and procurement decisions. Nevertheless, uncertainty does exist in the model as, at time period t, the values of per unit gross profit (R_{t+j}), the number of packers (N_{t+j}), and production costs (g_{t+j}, h_{t+j}) in future periods are uncertain.[1]

We substitute (7') into (9), obtain the first order conditions of the N_t packers, solve them simultaneously, and use equation (6) to find the equilibrium price and quantity in the cattle market as follows (see Crespi, Xia and Jones 2009 for a detailed derivation):

(10) $$\begin{aligned} P_t^* = {} & \beta_{1,t} R_t + \beta_{2,t} S_t + \beta_{3,t} E_t (P_{t+1}) + \beta_{4,t} E_t (P_{t+3}) + \beta_{5,t} E_t (h_{t+1}) \\ & + \beta_{6,t} E_t (h_{t+2}) + \beta_{7,t} E_t (h_{t+3}) + \beta_{8,t} + \beta_{9,t} \end{aligned}$$ and

$Q_t^* = f(P_t^*)$,

where

$\beta_{1,t} = N_t / (N_t + 1) \in [0.5, 1]$, $\beta_{2,t} = -g_t / (N_t + 1) M < 0$,

$\beta_{3,t} = (1-\delta) / (N_t + 1)(1+r) > 0$, $\beta_{4,t} = \lambda / (N_t + 1)(1+r)^3 > 0$,

$\beta_{5,t} = -\beta_{3,t} < 0$, $\beta_{6,t} = -(1+r)\beta_{4,t} < 0$, $\beta_{7,t} = -\beta_{4,t} < 0$,

$\beta_{8,t} = -\beta_{1,t}\left[(1-\delta)/M(1+r)\right] E_t\left(g_{t+1} Q_{t+1} / N_{t+1}\right) < 0$, and

$\beta_{9,t} = -\beta_{1,t}\left[\lambda / M(1+r)^3\right] E_t\left(g_{t+3} Q_{t+3} / N_{t+3}\right) < 0$.

We find $\partial|\beta_{j,t}| / \partial N_t < 0$ for j = 2, 3, …, 7, $\partial|\beta_{8,t}| / \partial N_{t+1} < 0$ and

$\partial|\beta_{9,t}| / \partial N_{t+3} < 0$.

In our model, the value of $\beta_{1,t}$ is an indication of beef packers' market power with $\beta_{1,t} = 1$ meaning perfect competition and $\beta_{1,t} = 0.5$ meaning monopsony.[2] $\beta_{1,t}$ also shows the proportion of the per-unit gross profit of beef packing that is passed on in the fed cattle price. If the cattle procurement market is perfectly competitive, the fed cattle price is equal to the per-unit gross profit R_t of beef packing. In this case, all supply factors including the adult cattle stock and the dynamic interaction between the current cattle procurement and future cattle stocks (represented by $\beta_{8,t}$ and $\beta_{9,t}$) have no effect on the fed cattle price. These results are as expected, however, other features of equation (10) are important to note, and we have laid these out in the following three propositions.

PROPOSITION 1: *The adult cattle stock has a negative effect (* $\beta_{2,t} < 0$ *) on the fed cattle procurement price if beef packers have market power in procurement while the cattle stock has no effect on the cattle price if the cattle procurement market is perfectly competitive. More* *importantly, the magnitude of the negative effect of the adult cattle stock on the cattle price is increasing* ($\partial\left|\beta_{2,t}\right|/\partial N_t < 0$) *in the degree of buyer market power in cattle procurement.*[3]

The effect described in proposition 1 has not been reported in previous studies. Namely, the cycle of adult stock not only implies a cycle of the bargaining position between cattle producers and beef packers, but that the fluctuation of this bargaining position is greater if the cattle procurement markets are less competitive. The economic insight behind this important result is straightforward. A larger adult cattle stock in the market means that the supply of cattle for slaughter is also larger. Thus, more cattle are procured by packers at the equilibrium. When beef packers have market power in cattle procurement, each packer finds her optimal quantity of cattle to procure where the marginal revenue from the last unit purchased and processed is equal to that unit's marginal expenditure (ME) of procurement. If the marginal revenue, R_t, is unchanged under different cattle stock levels, maintaining the same marginal expenditure of procurement with a larger quantity of purchases means that a packer's markdown, the difference between ME and the cattle price, must be larger because a packer knows that she has to pay the price increment caused by the purchase of the last unit for a larger quantity of cattle. A larger markdown and the same marginal expenditure indicate that the cattle price will be lower. When beef packers have more procurement power, each packer faces a steeper ME curve, i.e. the markdown is larger at a given quantity level and the markdown is increasing at a higher rate as the quantity increases. The higher increasing rate of markdown means an increase in cattle stock results in a larger markdown and, accordingly, a larger cattle price decrease. The negative effect of the adult cattle stock on the cattle price is magnified by the degree of buyer market power in cattle procurement. Figure 1 illustrates the price effect of the cattle stock in two scenarios with different levels of buyer market power.[4]

[Figure 1 Near Here]

PROPOSITION 2: *The dynamic interaction between current cattle procurement and future adult cattle stock causes further negative effects (represented by* $\beta_{8,t}$ *and* $\beta_{9,t}$*) on the current cattle price when packers have buyer power. Packers' current cattle procurement is negatively associated with their expected profits in future periods t+1 and t+3.*

Equation (10) also reveals that the functions $\beta_{8,t}$ and $\beta_{9,t}$ are negative. These conditions imply the results described in Proposition 2. The intuition behind proposition 2 is that additional current cattle purchases reduce the breeding stock; a lower breeding stock means that adult cattle stocks in the future are lower, and the lower future cattle stocks lead to higher cattle prices and lower profits in the future. Thus, this dynamic interaction reduces packers' incentives to purchase in the current period so that packers procure fewer cattle and the current cattle price is lower than what would prevail if the dynamic interaction did not exist. Similarly, the magnitude of the negative effects of this dynamic interaction on cattle prices is increasing in the degree of buyer market power over cattle procurements in future periods.

Equation (10) also shows the effects (represented by $\beta_{3,t}$ through $\beta_{7,t}$) of other supply factors on fed cattle price as set forth in proposition 3.

PROPOSITION 3: *When beef packers have market power in the cattle procurement market, in addition to the adult cattle stock itself, other supply factors can affect the fed cattle price. The price of cattle for slaughter is decreasing (increasing) in the cost (benefit) of keeping cattle in the breeding stock. That is, the cattle price is decreasing in the cost of maintaining breeding stock and future variable production costs and increasing in the producers' expectations of future cattle prices. The magnitudes of these price effects are also increasing in the degree of buyer market power in cattle procurement due to similar economic insights as those discussed above in the explanation of the cattle stock's price effect.*

An Empirical Examination

Based on the implications of our conceptual model, we propose a simple empirical study to examine the effects of cattle stocks, market power, costs of production, and other factors on the cattle price. The main contribution of the paper is the theoretical implication for the testing of market power in the cattle industry, but we hope that this empirical application can add insight into why researchers have been getting different results in the previously mentioned studies. In short, is there empirical evidence to suggest that the dynamic interaction between procurement and the cattle stock shown in the theoretical model needs to be taken into account when examining market power in this industry?

To build the empirical model, note that because $\beta_{5,t} = -\beta_{3,t}$, $\beta_{6,t} = -\left(1+r\right)\beta_{4,t}$, and $\beta_{7,t} = -\beta_{4,t}$, we can combine terms in equation (10). Noting the functional relationships among the parameters there and assuming a representative producer and packer have unbiased predictions for prices and quantities in future periods, the average price of cattle in year *t* can be estimated as:

(11)
$$\begin{aligned} P_t^* = {} & \beta_0 + \beta_{1,t}(N_t)R_t + \beta_{2,t}(N_t, h_t)S_t + \beta_{3,t}(N_t, r_t)[P_{t+1} - h_{t+1}] \\ & + \beta_{4,t}(N_t, r_t)[P_{t+3} - (1+r_t)h_{t+2} - h_{t+3}] \\ & + \beta_{8,t}(\beta_{1,t}(N_t), N_{t+1}, r_t, Q_{t+1}) + \beta_{9,t}(\beta_{1,t}(N_t), N_{t+3}, r_t, Q_{t+3}) \\ & + \varepsilon_t. \end{aligned}$$

Equation (10) and its empirical specification in equation (11) are non-linear and we imposed the theoretical constraint upon $\beta_{1,t}(\cdot)$ by letting $\beta_{1,t}(N_t) = \dfrac{1+\exp(\alpha_0 + \alpha_1 N_t)}{1+2\exp(\alpha_0 + \alpha_1 N_t)} \in \left[\dfrac{1}{2}, 1\right]$, however on the other $\beta_{i,t}(\cdot)$ *i*=2,…,9 functions we impose no sign constraints in order to test the theoretical implications. Specifically, we let, $\beta_{2,t}(N_t, h_t) = \alpha_2 h_t N_t^{-1}$, $\beta_{3,t}(N_t, r_t) = \alpha_3 N_t^{-1}(1+r_t)^{-1}$,

$\beta_{4,t}(N_t, r_t) = \alpha_4 N_t^{-1}(1+r_t)^{-3}$, $\beta_{8,t}(\beta_{1,t}(N_t), N_{t+1}, h_{t+1}, r_t, Q_{t+1}) = \beta_{1,t}(N_t)[\alpha_5 h_{t+1} Q_{t+1}(1+r_t)^{-1} N_{t+1}^{-1}]$, and

$\beta_{9,t}(\beta_{1,t}(N_t), N_{t+3}, h_{t+3}, r_t, Q_{t+3}) = \beta_{1,t}(N_t)[\alpha_6 h_{t+3} Q_{t+3}(1+r_t)^{-3} N_{t+3}^{-1}]$, where β_0 and α_j, j =0, 1, …, 6, are parameters to be estimated. We used SAS's nonlinear optimization routine to derive the estimators, including an intercept, β_0, to aid in convergence by accounting for divergences from the mean due to the functional specifications we have made above. The error term ε_t is assumed to have a zero mean and is normally distributed.[5]

Data

The data consist of 293 monthly observations from January 1988 to December 2006. In the conceptual model, the time period, *t*, was years. In the empirical model, the time period is months, *m*, hence *t*+1, *t*+2 and *t*+3 in the conceptual model translate as *m*+12, *m*+24 and *m*+36**,** respectively in the empirical model. We will continue to use the *t* notation in this section for consistency. In lieu of a good proxy for expected values, following Becker, Grossman and Murphy (1994) we simply use the actual values in time periods *t*+1 and *t*+3. All prices and costs have been converted into real (2008) dollars using the consumer price index. The price ($/cwt) for live cattle sold to beef packers each month, P_t, is obtained by averaging the reported USDA/AMS weekly prices for each month (dressed cost basis) for steers. This price in real terms averaged $121/cwt with a minimum of $75 and a high of $228.

For N_t we used the annual number of federally-inspected beef-packing plants reported by the U.S. Department of Agriculture (2002, 2008) in their annual packers and stockyards statistical reports. Although the number of plants is not the same as the number of firms, Crespi and Sexton (2005) found evidence that plants, rather than firms could be a good proxy and we do not have data on the number of firms over time.[6] One must be mindful about the use of the number of packing plants as a measure of competition in an industry. As Demsetz (1973) has opined, a market that is very competitive may be either increasing or decreasing in concentration. A highly concentrated market may indicate market power, but it may also be the result of fierce competition with only the least-cost firms surviving. Hence, while the theoretical model could assert that N_t was synonymous with competition, in the real world, the relationship is not as clear. In our study, N_t fell almost linearly from 461 in 1988 to 168 by 2006 with a mean of 264 and in many ways performed the same function as a simple trend.[7] Future research should consider alternative measures for competition.

R_t is the value for the processed beef less cost of production. We use the U.S. Department of Agriculture's AMS reported weekly price ($/cwt) of boxed beef (averaging the price of "choice" and "select") and average weekly prices into a monthly value. On average this boxed-beef price was $164/cwt ranging from $121 to $230. For costs we use the annual measure of operating costs as a percentage of sales for the top 40 beef packing firms as reported by the U.S. Department of Agriculture (2002, 2008) in their annual packers and stockyards statistical reports. These cost data exist from 1992 to 2006, average 18.95 percent ranging from a low of 15 to a high of 24 percent. The values have trended upward in a nearly linear manner over the time period and a simple linear trend line fit to these data had an R^2 of 0.90. We thus used the estimated trend for the time period in our study. As these costs are reported on a percentage of sales basis, we estimated R_t as one minus the operating expense multiplied by the price of the boxed beef.

We do not have detailed data on the monthly size of the stock of cattle, thus the adult cattle stock, S_t, is the annual U.S. Department of Agriculture estimate of the number of head in the adult herd in the U.S. and remains constant for a given year. S_t averaged roughly 100 million head ranging from 95 million to 114 million head per year. The number of head slaughtered, Q_t, is a monthly average of the weekly reported numbers collected by the U.S. Department of Agriculture. The slaughter averaged 2.2 million from a minimum of 519 thousand to a maximum of 3 million head. Both S_t and Q_t are measured in 1000s in the model. r_t is the interest rate on agricultural lending loans for operations in the 10th Federal Reserve District (Federal Reserve Bank of Kansas City) and varied from a low of 7% to a high of 18% with an average of 10.7% over the time period. The variable cost of producing cattle is dependent on a variety of factors. Extension economists at Kansas State University have developed a monthly break-even price ($/cwt) that shows the minimum price an average producer would have to receive in order to just cover her costs of production (Kansas State University 2008). Rather than constructing our own measures, we use this value to measure costs of production for cattle producers. Unfortunately, we are unable to break out the portion of these costs that would go to maintaining a feeding stock (g_t in the theoretical model), hence we use h_t where both g_t and h_t appear in the theoretical model. Future research would improve on the estimation with more precise measures of these costs no doubt. Although the value is derived for cattle in Kansas, because the majority of U.S. cattle are fed in the high-plains region and because this value has been shown to be consistent with similar values estimated for cattle in other states, we feel it is a good approximation for a national cost variable and has the advantage of being the only cost variable of its type that covers the span of our data set. This value had an average of $103/cwt and varied from $77 to $139/cwt.

Results

Estimation of equation (11) allows us to examine the effect on buyer market power in cattle markets over a long period of time without imposing any static constraint on the estimate of market power. Equation (11) not only shows us how cattle prices have changed over time as the stock of cattle has changed ($\beta_{2,t}$) and the price effects of the dynamic interaction between current cattle procurement and future cattle stock ($\beta_{8,t}$ and $\beta_{9,t}$), but also how market power as measured by $\beta_{1,t}$ changes over the time period under study and magnifies the price effects of cattle stock, the dynamic interaction in the cattle cycle, and other supply factors.

[Table 2 about here.]

Table 2 shows the parameter estimates of equation (11) along with the statistics for the various functions. The fit as measured by the R^2 is very high, not surprising given the number of time-series observations.[8] The signs are as predicted by the conceptual model for all parameters save one with five of eight coefficients significant at the 5-percent level and six of eight significant at a ten-percent level. The only parameter with a questionable sign is α_1 in $\beta_{1,t}$. The reader can confirm that a positive sign on α_1 means that as N_t increases, $\beta_{1,t}$ goes to ½. As discussed, there is no reason why competition and N_t are inversely related in reality. Declining numbers of firms may just as easily indicate a highly competitive market if competition has driven out inefficient firms. Recall, by the end of our sample, N_t was in fact 168, hardly a small number. Combining that with the fact that N_t may be acting as a simple trend, we also tried the model with and without a trend with no appreciable difference. Thus, like Stiegert, Azzam and Brorsen (1993), we also find that market power is negatively correlated with concentration over time in the beef processing industry. Two of the parameter estimates in the $\beta_{3,t}$ and $\beta_{8,t}$ functions (α_3, α_5) cannot be considered different from zero although an F test revealed that jointly all coefficients were significant at a 5-percent level. All of the parameters in the remaining functions are significant. Table 2 shows some statistics of interest for the various functions.

The market power function, $\beta_{1,t}$, has a mean of roughly 0.8, which indicates that overall in this data series the market could be classified as non-competitive though farther on average from the monopsony level of ½ and closer to the perfectly competitive value of 1. This suggests that over the period of study, buyer power could be classified as an oligopsony, which is in line with many of the studies discussed previously. To discuss this and the other functions with respect to the time period of our data set, we present figures 2 through 5 in order to put the concept of buyer power in the context of the cattle cycle.

[Figures 2, 3, 4 and 5 can be placed anywhere in this section near the following four paragraphs.]

Figure 2 shows the cattle cycle over the time period along with the percentage markdown from a hypothetically competitive cattle price. We determine this price by setting $\beta_{1,t} = 1$ in equation 11, subtracting the result from the actual cattle price then converting this to a percentage. Our average percentage markdown is somewhat larger than those found in the majority of studies (our average is 20 percent whereas most studies find average markdowns below 10 percent), though as is evident these markdowns have fallen to lower levels recently, in line with the levels found in recent studies. The estimated markdowns support the main hypothesis of this paper. The percentage markdown from the competitive level clearly follows the cattle cycle. Hence comparisons of previous studies that find conflicting levels of buyer market power need to be assessed in this light. In the remaining figures, we break down the dynamics of this effect.

Figure 3 compares the functions $\beta_{1,t}$ and $\beta_{2,t}$. As Stiegert, Azzam and Brorsen (1993) found, we too find that market power has been declining over time ($\beta_{1,t}$ is getting larger in our study) even as concentration in the processing market has been increasing. However, we also find that the general trend on what we term the "magnification effect" of market power ($\beta_{2,t}$) is becoming more negative over the same time period. In other words, even though procurement markets have become more competitive, the magnification of market power on the cattle stock's negative price effect today is larger than it was in the past. This is seen in figure 2, as well, where the percentage markdown is generally declining (more competitive) as stocks have declined over time, but at the same time has become more volatile because the magnification effect is increasing (in absolute value). This important and previously unrecognized phenomena adds further credence to the assertion that previous measures of market power may differ importantly because of the time periods under study. As our theoretical model predicted and as our empirical model seems to support, there is an implication for regulators here. In short, even if the industry is becoming more competitive, the potential impact from market power is greater today than in the past. The US Department of Justice may have recognized this when it allowed JBS to recently acquire Swift's and Smithfield's beef processing units but balked at JBS' further reach for National Beef.

The effects from the other functions on the price of cattle are shown in figures 4 and 5. In figure 4, $\beta_{3,t}$ and $\beta_{4,t}$ are positive and increasing over time. (Recall, $\beta_{5,t}$, $\beta_{6,t}$, and $\beta_{7,t}$ are derived from $\beta_{3,t}$ and $\beta_{4,t}$ but with opposite signs.) What figure 4 implies is that both expectations of future prices of cattle and future costs of production have more of an effect today on the going cattle price than they did in the past. Two possible reasons for this come to mind. First, on the production side, using data from 1988 to 1993, Kastens and Schroeder (1994) found that producers were less forward looking than expected profit models suggested they should be. It would be useful to examine their study with current data to see if producers today are more likely, for example, to hedge (i.e. forecast future profit) than in the past when Kastens and Schroeder (1994) examined this issue. Second, even though we find less buyer power being exercised today than in the past, we also find there is more potential for market power than in the past. Monopsony behavior is more consistent with adjusting present prices in the face of expected cost changes than is perfectly competitive behavior. Hence, both on the production side and the procurement side there is need for further analysis.

Finally, figure 5 shows $\beta_{8,t}$ and $\beta_{9,t}$ are approaching zero with much more variability than the other functions. These functions are difficult to interpret but show the dynamic interactions between current cattle procurement and future cattle stocks and indicate that these relationships are correlated with a diminishing of buyer power over time. This effect has not been reported elsewhere and we admit being puzzled by its implication. We consulted several livestock extension economists, none of whom could either confirm or deny the effect but did speculate about why it may occur. One reason may be that in more recent years producers have become involved in more operations than cattle. Another reason may be due to transportation logistics today being better than in the past. Both may mean that producers today are less influenced by processor procurement power because their livelihood is not dependent solely on cattle and/or because today they can ship cattle from a low-paying region to a higher paying one with more alacrity. Whatever the reason, the effect certainly warrants further research.

We acknowledge the well-known limitations of any aggregate data series and in this case especially regarding the assumptions we made in terms of costs, competition and other variables. Nonetheless, the results of the empirical model are intriguing and warrant further study. The main implication for the empirical model as shown in figures 2 through 5 are these. First, although no sign restrictions were placed on them, the functions $\beta_{2,t}$ through $\beta_{9,t}$ conform to the hypotheses of the theoretical model. Second, the empirical model indicates that buyer market power has declined over time ($\beta_{1,t}$ has become larger), consistent with the findings of SAB. Third, market power, if it exists, has a potentially bigger effect today ($\beta_{2,t}$) than in the past. Fourth, market power, may be less affected by processors' manipulation of the cattle cycle today ($\beta_{8,t}$ and $\beta_{9,t}$). Finally, in support of the key implication of the theoretical model, markdowns definitely rise and fall with the cattle cycle.

Conclusion

The motivation for this work is twofold. First of all, there is a well documented effect known as the cattle production cycle. Secondly, cattle markets, especially the procurement of fed cattle for slaughter have been studied at length by economists trying to discern the amount of buyer market power, with mixed results. Nonetheless, whether there is any relationship between the areas of research has been mostly overlooked.

This paper develops a conceptual model that incorporates first, producers' decisions to sell some female adult cattle to be slaughtered and to keep the remaining female adult cattle for breeding, and, second, packers' decisions to purchase cattle knowing that the amount purchased will affect future stocks and, hence, future profit. The conceptual model yields the following results.

A larger cattle stock does not simply lead to a lower fed cattle price; the cattle stock's negative effect on price is magnified by any buyer market power in cattle procurement. Thus, the cycle itself is very importantly related to a posited cycle of bargaining position between cattle producers and beef packers. In a less competitive market, beef packers' markdowns will increase at a higher rate as quantity increases so that an increase in cattle stock will result in a larger cattle price decrease.

Moreover, the conceptual model also shows that the dynamic interaction between current cattle procurement and future adult cattle stocks can reduce current cattle prices. In essence, purchasing one more animal today not only raises the current cattle price, but also increases future cattle prices by reducing future cattle stocks due to a lower current breeding stock. Thus, packers may procure fewer cattle in the current period and the equilibrium cattle price is lower than what would prevail if the dynamic interaction did not exist. Claims that packers use their positions in futures markets to affect spot market prices have been made by some producer groups, but this is the first model of which we are aware to demonstrate that current spot purchases may be rationally used to affect future spot markets and, in fact, current and future spot markets are linked in the packer's procurement function.

Thus, on its own, the conceptual model is a valuable contribution to an understanding of market power in cattle markets. One should expect that in periods of large national and regional supplies, feedlots have lower bargaining power than when supplies are tight. We are aware of no study that examines whether this explains why different researchers come to such different conclusions, but if it is indeed the case, it may go a long way to explaining why in this particular market when stakeholders pressure regulators to examine the issue, by the time data are assembled and studied, the effects may disappear.

To test this idea, the conceptual model lent itself to an empirical specification that includes cattle stocks and the dynamic interaction between procurement and inventories and allowed for a parameterization of the price effects of various cost and market variables that can change over time. As previous studies have either treated the market power parameter as fixed (Azzam and Pagoulatos 1990; Morrison Paul 2001) or have examined a time series too short to take the cattle cycle into account (Morrsion Paul 2001; Crespi and Sexton 2005), this model has a new conceptual foundation to include the cattle cycle, allows flexibility, and uses a long time series to study cattle price and markdowns throughout the cycle.

The empirical model upheld the general findings of the conceptual model. First, times of higher cattle supplies are correlated with periods of higher markdowns. Secondly, although we find as have other authors that market power has declined recently, we are the first to show that the effect of market power on price is more variable today than in the past. We also find that the relationship between future prices and future costs is stronger today than in the past and that the dynamic interaction between cattle procurement and future stocks has less of an effect today than in the past. The fact that the empirical model upholds the main findings of the conceptual model, and is the first to demonstrate the relationship between market power and the stock magnification effect due to the cattle cycle is an important first step to understanding these highly cyclical markets. Future research using firm-level data sets as have been obtained in a few studies (Morrison Paul 2001; Schroeter and Azzam 2003; Crespi and Sexton 2005) should reexamine these implications.

These findings have never been discussed in the previous research and have important implications to policy makers and regulators charged with overseeing competitive livestock markets. At a time when the buyer concentration is increasing, the need to understand the impact of the cattle cycle on market power and vice versa will only increase.

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[1] In the extreme cases of a known monopoly at time period t ($N_t = 1$) or known perfect competition at time period t ($N_t \to \infty$), we assume that near future values of N will remain unchanged, otherwise we would have to enter into messy and probably unreasonable assumptions about the stochasticity of market openness.

[2] In the theoretical model we can simply assert the relationship between N_t and market power such that $N_t \to \infty$ under perfect competition and $N_t \to 1$ under monopsony at any t, but we reconsider the complexities of the relationship in the empirical estimation.

[3] Recall, in the conceptual model a smaller value of N_t indicates more procurement power.

[4] In figure 1, a stock increase from S_0 to S_1 will reduce the cattle price in both case (a) and (b), but the cattle price decrease ($P_0^b - P_1^b$) in case (b), in which buyer market power is stronger, is larger than the cattle price decrease ($P_0^a - P_1^a$) in case (a).

[5] Because of the potential for autocorrelation due to the leads, we also estimated the model using a 1-, 2- and 3-year autocorrelation correction. Further, although our conceptual model treated cattle stock as predetermined at time t, in response to a reviewer we also estimated three additional specifications i) treating S_t as a function of P_t alone, ii) treating S_t as a function of P_t and all other contemporaneous variables, and iii) treating S_t as a function of P_t and all of the other variables in equation (11) with U.S. population at time t as an added instrument. The results for both the autocorrelation correction models and the endogenous cattle stock models were so similar to the results for the model presented here that we do not include them to save space.

[6] We also estimated the model using an industry Herfindahl index. The results were similar but overall the econometric estimates were not as good.

[7] The Herfindahl index and the 4-firm concentration ratio likewise increased almost linearly over the same period.

[8] The R^2 is calculated as $1 - SSE / [SSP - n\overline{P}^2]$ where SSE is the sum of squared errors, SSP is the sum of squares of the observed dependent variable P_t, n is the sample size and $\overline{P}$ is the mean of P_t.

Table 1. Literature on Market Power in Cattle Procurement.

Study	*Evidence of Market Power?*	*Time Period in Study*
Schroeter (1988)	–	1951-1983
Azzam (1992)	+	1988-1991
Schroeter & Azzam (1990)	+	1976-1986
Azzam & Park (1993)	–	1955-1977
Azzam & Park (1993)	+	1982-1987
Koontz, Garcia & Hudson (1993)	+	1980-1982
Koontz, Garcia & Hudson (1993)	+, but lower than in 80-82	1984-1986
Stiegert, Azzam & Brorsen (1993)	+	1972-1986
Morrison Paul (2001)	–	1992-1993
Crespi & Sexton (2005)	+	1995-1996

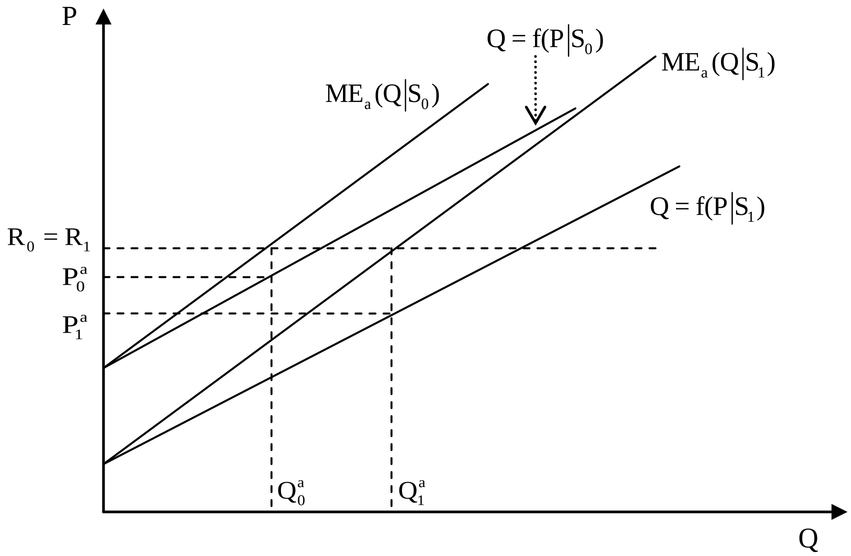
Notes: "–" means little to no evidence of buyer market power; "+" means evidence of market power.

Table 2. Empirical Estimation of Cattle Prices.

Parameter	Estimate	Std Err		
β_0	6.640*	2.989		
α_0	-2.650*	0.202		
α_1	3.76E-03*	3.15E-04		
α_2	-1.70E-04*	7.10E-05		
α_3	2.460	7.671		
α_4	7.970*	3.822		
α_5	-2.00E-05	8.72E-06		
α_6	-1.00E-05+	1.10E-05		
R^2	0.972			
Function	Mean	Std Err	Min	Max
$\beta_{1,t}$	0.817	0.071	0.668	0.896
$\beta_{2,t}$	-5.851E-05	1.833E-05	-1.08E-04	-3.24E-05
$\beta_{3,t}$	0.008	0.004	0.003	0.014
$\beta_{4,t}$	0.020	0.010	0.007	0.040
$\beta_{5,t}$	-0.008	0.004	-0.014	-0.003
$\beta_{6,t}$	-0.043	0.021	-0.082	-0.015
$\beta_{7,t}$	-0.020	0.010	-0.040	-0.007
$\beta_{8,t}$	-0.819	0.511	-2.398	-0.252
$\beta_{9,t}$	-0.723	0.436	-2.123	-0.082

Note: dependent variable is the price of cattle ($/cwt); 293 monthly observations; * indicates a 5% significance level; + indicates significance at 10%; time period is 1988-2006.

(1a): the case with N=2



(1b): the case with N=1

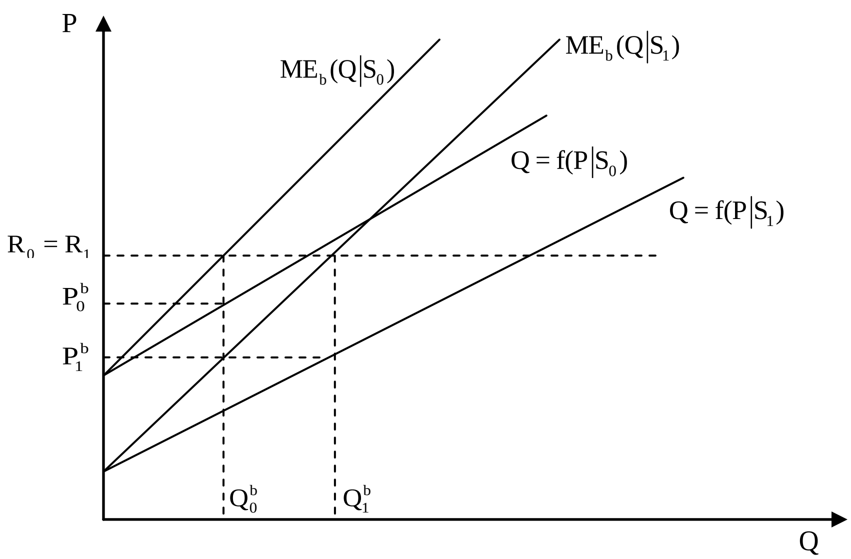


Figure 1. The Effect of Adult Cattle Stock on Cattle Procurement Price.

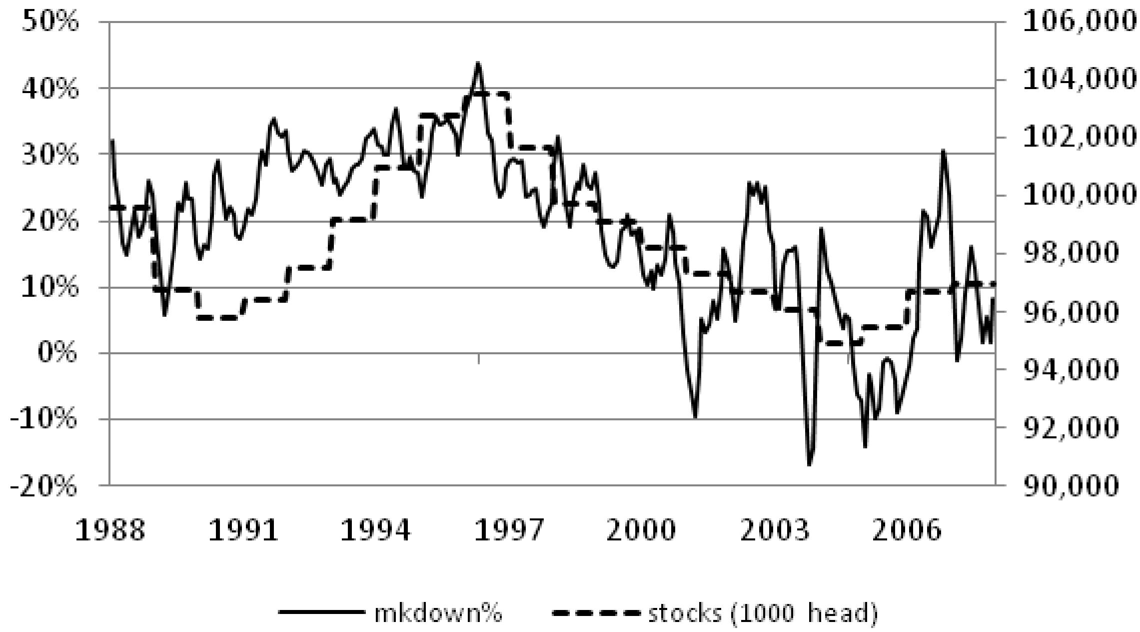


Figure 2. Oligopsony markdown follows the cattle cycle.

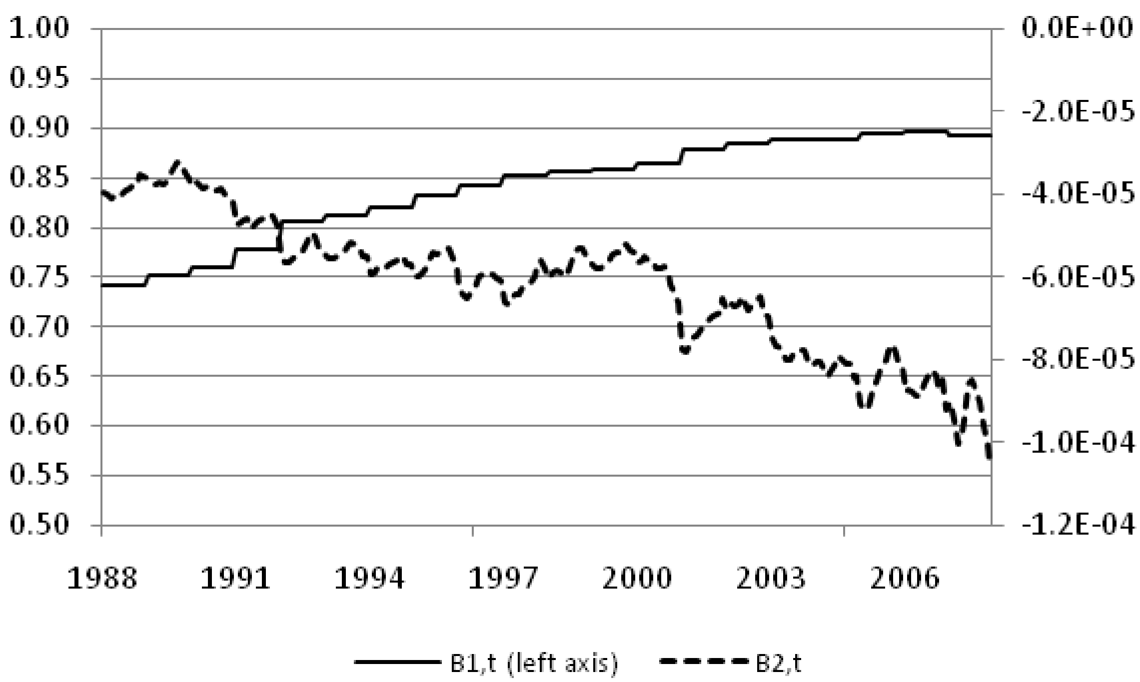


Figure 3. Market power has declined ($B_{1,t}$ has increased) but the magnification effect ($B_{2,t}$) has increased in absolute value over time.

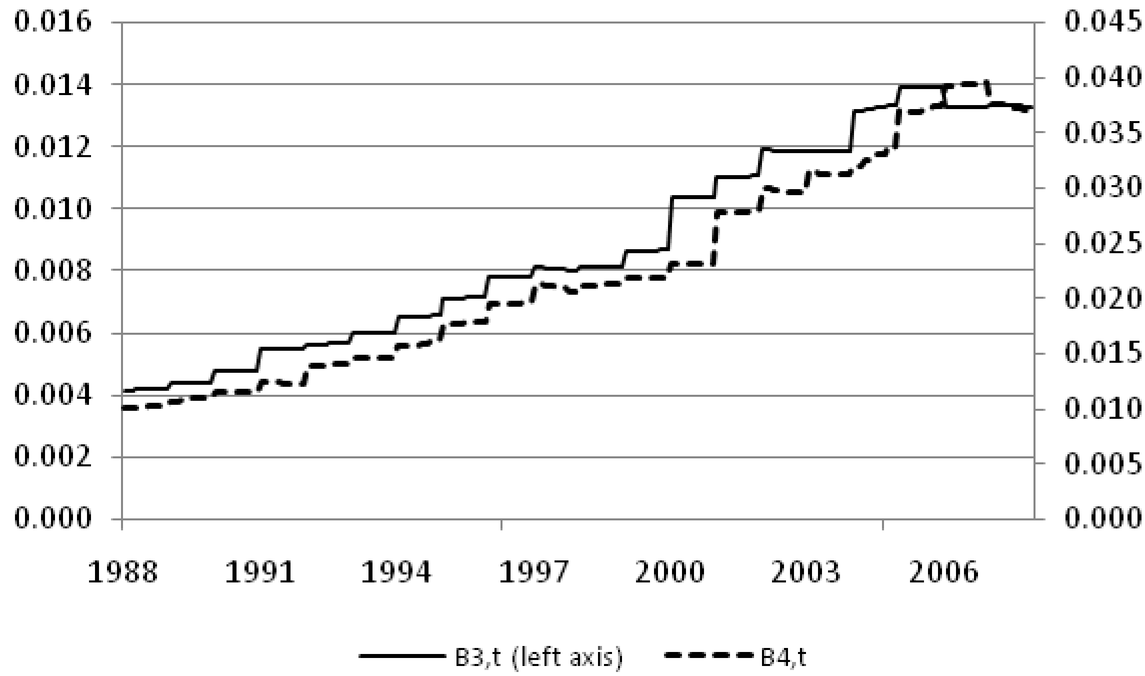


Figure 4. Price (and cost) expectations today have more of an effect on prices than in the past.

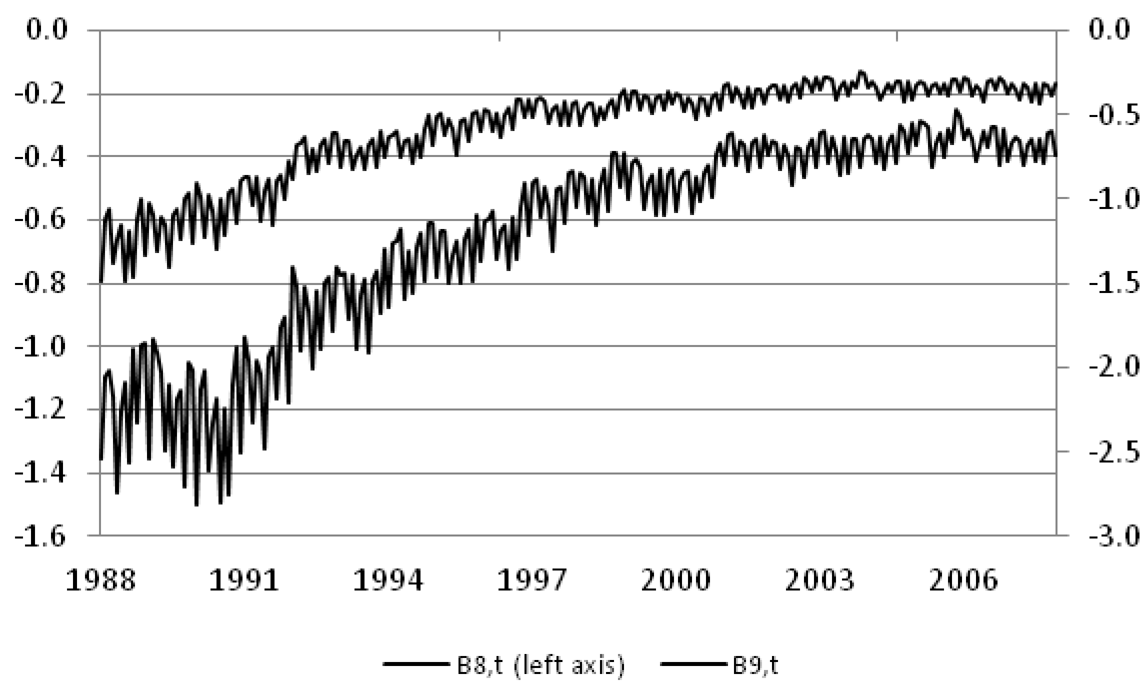


Figure 5. The dynamic interactions of current cattle procurement and future cattle stocks have lessened the effect of buyer power over time.