THREE ESSAYS ON MARKET POWER

IN THE U.S. CATTLE PROCUREMENT MARKET

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ESSAY I

CAUSALITY BETWEEN CAPTIVE SUPPLIES AND CASH MARKET PRICES IN THE U.S. CATTLE PROCUREMENT MARKET

Introduction

Several studies in the cattle procurement literature have reported a negative relationship between cash market price and captive supply (Elam 1992; Schroeder et al. 1993; Ward et al. 1996; Ward, Koontz, and Schroeder 1998; Schroeter and Azzam 2004).[1] One justification of the negative relationship is that the captive supply procurement methods could lower cattle prices in the cash market because the packers are already guaranteed a majority of cattle for slaughter (Zhang and Sexton 2000). A second justification is that captive supply sellers may control delivery time to receive the highest expected price (Schroeter and Azzam 2004). Therefore, when expected cash market price is low, captive supply would increase. The price dependent model is based on the first justification, while the second justification leads to the quantity dependent model in the literature.

The two justifications are well reflected in the case of Pickett vs. Tyson Fresh Meats (Domina 2004; Taylor 2006). The plaintiff insisted that captive supplies caused low cash market price, while the defendant claimed that captive supply did not establish the causation. The dependant claimed producer expectations of price caused producers to deliver more captive supply in the week when prices went down for other reasons. Initially, Tyson was ordered by the U.S. District Court to return $1.28 billion to all cattle producers who sold fed cattle directly to Iowa Beef Processor (IBP, now Tyson Fresh Meats) from February 1994 through April 30, 1999. However, the U.S. District Court Judge entered a final judgment in Tyson's favor in 2004. Finally, the U.S. Supreme Court denied the appeal of the lower-court decision in April 2006. Therefore, a crucial task in the literature of captive supply should be to investigate the causality between cash market prices and captive supplies. However, to our knowledge, no study has examined the causality directly. Finding the correct causal direction should provide useful information to the decades-long debates on packers' anticompetitive behavior in the U.S. cattle procurement market, and should also help researchers find better econometric specifications for the cash price-captive supply relationship.

The objective of this study is to investigate the causality between captive supplies and cash market prices in the U.S. cattle procurement market. The study particularly attempts to answer the question of whether packers use predetermined captive supply as an instrument to depress cash market price, or if feeders use the previous cash market prices as expected prices they will receive in the future to determine their cattle delivery. The Granger causality Wald test (Granger test), the Sims causality Wald test (Sims test), and the Granger causality with a modified Wald test (Modified Wald test) are used to examine the causality using weekly data of captive supply quantities and cash market prices in the U.S. cattle procurement market. We test the causal relationship between cash market price and total captive supply, and also test the relationships between cash market price and each of the captive supply methods, such as marketing agreement, forward contract, and packer-fed cattle.

All three tests, the Granger, the Sims, and the Modified Wald tests, indicate that cash market price is affected by total captive supply and marketing agreements. The Modified Wald test shows the bidirectional causality between cash market price and forward contract. This test also shows that packer-fed cattle do not cause cash market price and vice versa. The Granger and the Sims tests were not conducted for forward contract and packer-fed cattle because quantity and price series are differently integrated. Overall test results indicate that captive supply causes cash market price, and the results favor the price dependent model.

Literature Review

Two types of modeling approaches have been used in the literature to explain the negative relationship between captive supply and cash market price: the price dependent model and the quantity dependent model. Some researchers assume that packers' captive supplies negatively affect cash market prices and model the relationship using the price dependent model (Elam 1992; Schroeder 1993; Ward, Koontz, and Schroeder 1998; Zhang and Sexton 2000). Both Elam (1992) and Schroeder (1993) estimate the impact of forward contract on cash price by regressing cash price on contract cattle shipments and other independent variables. Elam (1992) estimates that the average cash price of fed cattle decreases by less than $0.01/cwt for each increase of 1,000 head of contract cattle shipments, and Schroeder (1993) estimates that average fed cattle cash transaction prices are lowered by $0.15/cwt to $0.31/cwt as a result of forward contract cattle shipments.

Ward, Koontz, and Schroeder (1998) model transaction prices as a dependent variable and percentage deliveries from the inventory of forward contracted and marketing agreement cattle as independent variables. They find a negative relationship between fed cattle transaction prices and captive supplies, but corresponding coefficients are relatively small. Zhang and Sexton (2000) develop a non-cooperative game approach in a spatial analysis setting to show that processors can use exclusive contracts (captive supplies) to manipulate cash market prices. The study demonstrates that captive supplies can form an effective spatial barrier between firms through high buyer concentration and shipping costs.

Others use quantity dependent models because they believe the quantities of delivery are determined by the expected price that sellers can be paid when they deliver their cattle to packers in the future. Schroeter and Azzam (2004) and Schroeter (2007) find that cash market prices or expected cash market prices form the negative relationship with delivery of captive supplies. Schroeter and Azzam (2004) insist that delivery-scheduling decisions could lead to a negative relationship between the volume of captive deliveries and an ex ante expectation of a future price change in the cattle procurement activities of four large packing plants in Texas in the mid-1990s. Schroeter (2007) extends Schroeter and Azzam (2004) to a dynamic rational expectations model of delivery timing. He claims that sellers of marketing agreement and cash market have flexibility in scheduling cattle delivery while responding to changes in expected cattle price.

Ward et al. (1996) use a quantity dependent model for the long-run analysis while it uses a price dependent model for the short-run analysis. In the long-run analysis, the plant-level study finds that relative prices play a major role in determining the level of captive supplies for the 16 largest plants, but do not influence captive supply levels of the 15 small plants. The study also finds that cash price variability is positively associated with the level of contract cattle for the 16 largest plants, but is not a determinant of packer-fed cattle or total levels of captive supplies. In the short-run analysis, Ward et al. show that the overall short-run impact of captive supply deliveries or inventories on fed cattle transaction prices is relatively small.

As discussed, previous studies in the literature use either price dependent model or quantity dependent model to explain the negative relationship between captive supplies and cash market prices. However, no study in the literature has directly tested the causal direction between captive supply and cash market price.

Captive Supply Arrangements in the Cattle Procurement Market

Captive supplies include marketing agreement, forward contract, and packer-fed cattle in the cattle procurement market. For marketing agreement, a feeder and a packer make a contract which contains a price formula and an approximate number of cattle scheduled for delivery per year. Generally the feeder makes a decision about two weeks before the time of delivery on the amount of cattle to deliver to the packer for each week. When the delivery volume is set by the feeder for a given week, the packer usually decides the specific day or days of the week when delivery will be made. The price of cattle delivered through marketing agreement is calculated by several formulas which include base price, system of premia and discounts, and quality characteristics such as yield grade, quality grade, and carcass weight range. The base price is tied to the cash market prices paid the week prior to delivery of the marketing agreement cattle (Schroeter and Azzam 2004). For forward contract, the feeder delivers a specific number of cattle to the packer within a specific month. However, unlike the case of marketing agreements, the packer decides the scheduling of deliveries across weeks and days within the month. The number of forward contract cattle delivered in a given week is normally decided either one or two weeks in advance (Schroeter and Azzam 2004). The feeder and packer use basis forward contracting to price the forward contract cattle (Ward et al. 1996).[2] Packer-fed cattle are owned by the packer prior to the time the cattle are ready for slaughter. Packers purchase feeder cattle and place them on feed in packer-owned or commercial feedlots. They are priced by a transfer pricing formula or cost accounting price (Ward et al. 1996).

Causality Tests

To investigate the direction of the causal relationship between captive supply and cash market price in the cattle procurement market, three causality tests: the Granger test, the Sims test, and the Modified Wald test are used in this study.

Granger Test

In the Granger test, a variable x causes a variable y, if a variable y can be predicted with greater accuracy by using past values of a variable x rather than not using such past values while all other terms remain unchanged (Granger 1969). Three types of causality are feasible for our study. First, if $x(y)$ causes $y(x)$, but $y(x)$ does not cause $x(y)$, then a directional causality exists. Second, if x causes y, and y causes x, then a bidirectional causality (feedback) exists. Finally, the third causality type is that the direction cannot be determined.

Various ways to test for Granger causality exist. However, the most popular one is the one following a vector autoregressive (VAR) system as:

(1.1) $$y_t = \alpha_1^G + \sum_{i=1}^{n} \beta_i^G x_{t-i} + \sum_{j=1}^{m} \gamma_j^G y_{t-j} + \varepsilon_{1t},$$

(1.2) $$x_t = \alpha_2^G + \sum_{i=1}^{n} \delta_i^G x_{t-i} + \sum_{j=1}^{m} \eta_j^G y_{t-j} + \varepsilon_{2t},$$

where y_t and x_t are assumed to be stationary, n and m are numbers of lags, and ε_{1t} and ε_{2t} are white noise disturbances.

The variable x_t does not cause y_t if $\beta_i^G = 0$ for $i = 1, 2, \ldots, n$ and $\gamma_j^G \neq 0$ for $j = 1, 2, \ldots, m$, but the variable y_t causes x_t if $\eta_j^G \neq 0$ and $\delta_i^G \neq 0$. The implication of this model structure is that values of the process y_t are influenced only by its own past but not by the past of x_t, while values of x_t are influenced by the pasts of both x_t and y_t. A Wald test is used to test these hypotheses.[3] Before applying the Granger test procedure, a pre-test needs to be conducted for potential unit root and cointegration problems. Then, the causality test is undertaken within the framework of VAR models (Konya 2004).

Sims Test

The Sims causality test (1980) is based on a notion that the future is not likely to cause the present. Therefore, in the Sims's framework, the causality is tested via the following VAR model:

(1.3) $$y_t = \alpha_1^S + \sum_{i=1}^{n} \beta_i^S x_{t-i} + \sum_{j=1}^{m} \gamma_j^S y_{t-j} + \sum_{\rho=1}^{k} \phi_\rho^S x_{t+\rho} + v_{1t},$$

(1.4) $$x_t = \alpha_2^S + \sum_{i=1}^{n} \delta_i^S x_{t-i} + \sum_{j=1}^{m} \eta_j^S y_{t-j} + \sum_{\rho=1}^{k} \pi_\rho^S y_{t+\rho} + v_{2t}.$$

In this model, the causality test is conducted by testing for the leading values of x_t and y_t instead of testing for the lagged values of x_t and y_t. If the parameters of the leading value of x_t are not zero, i.e., $\phi_\rho^S \neq 0$ for $\rho = 1, 2, \ldots, k$, then y_t causes x_t, and if the parameters of the leading value of y_t are not zero, i.e., $\pi_\rho^S \neq 0$ for $\rho = 1, 2, \ldots, k$, then x_t causes y_t. The Sims test also uses the Wald test for the hypothesis tests.

Modified Wald Test

Both the Granger and Sims tests require time-series data pre-tested for potential unit root and cointegration problems (Konya 2004). When variables are stationary and are not cointegrated, then conventional asymptotic theory is valid for hypothesis testing in the VAR models. If variables are cointegrated, then one can use Error Correction Models (ECM). Therefore, one limitation of the Granger and the Sims tests may be that the direction of causality depends severely on pretests, more specifically unit root and cointegration tests. Toda and Yamamoto (1995) propose an alternative causality test, the Modified Wald test, that does not require any pretests. Unlike the Granger and the Sims tests, the Modified Wald uses the level data directly and therefore is valid even under uncertainty about integration and cointegration (Konya 2004).

The Modified Wald test is conducted in VAR systems with augmented lag levels, $n + d$ and $m + d$, where n and m are the lag length for the variables, and d is the highest order of integration suspected in the system. Then, a bivariate framework for the Modified Wald test can be written as:

$$(1.5)\qquad y_t = \alpha_1^M + \sum_{i=1}^{n} \beta_i^M x_{t-i} + \sum_{i=n+1}^{n+d} \beta_i^M x_{t-i} + \sum_{j=1}^{m} \gamma_j^M y_{t-j} + \sum_{j=m+1}^{m+d} \gamma_j^M y_{t-j} + u_{1t},$$

$$(1.6)\qquad x_t = \alpha_2^M + \sum_{i=1}^{n} \delta_i^M x_{t-i} + \sum_{i=n+1}^{n+d} \delta_i^M x_{t-i} + \sum_{j=1}^{m} \eta_j^M y_{t-j} + \sum_{j=m+1}^{m+d} \eta_j^M y_{t-j} + u_{2t}.$$

In this model the null hypothesis is $\beta_i^M = 0$ for $i = 1, 2, \ldots, n+d$ and $\eta_j^M = 0$ for $j = 1, 2, \ldots, m+d$, and the test statistic follows an asymptotic χ^2 distribution with the usual degrees of freedom, $n+d$ and $m+d$ (Toda and Yamamoto 1995). If the parameters of the value of x_t are not zero, i.e., $\beta_i^M \neq 0$ for $i = 1, 2, \ldots, n+d$, then x_t causes y_t, and if the parameters of the value of y_t are not zero, i.e., $\eta_j^M \neq 0$ for $j = 1, 2, \ldots, m+d$, then y_t causes x_t.

Data

This study uses aggregate captive supply quantities of five regions including Texas/Oklahoma/New Mexico, Kansas, Nebraska, Colorado, and Iowa/Minnesota, and the cash market price is the weighted average price on a live weight basis of these five regions.[4] Data were compiled from various reports from the Agricultural Marketing Service, USDA (USDA 2008). The data include 351 weekly observations of total captive supplies of cattle procurement from marketing agreement, forward contract, and packer-fed cattle plus cash market price from August 2001 to May 2008.

Table I-1 shows the descriptive statistics for the data. During the data period, the average cash market price was $82.98 per hundredweight of cattle, and total captive supply accounted for 53.2% of all cattle procurement. Of the total captive supply, marketing agreement, forward contract, and packer-fed cattle accounted for 76.0%, 10.7%, and 13.3%, and of all cattle procurement, accounted for 40.6%, 5.7%, and 7.0% respectively.

As shown in table I-2, the correlation matrix of the five variables indicates a negative correlation of 62% between total captive supply and cash market price and a negative correlation of 72% between marketing agreement and cash market price. These negative correlations are already expected from previous studies discussed earlier. Forward contract reveals a positive correlation with cash market price. The correlation coefficient between cash market quantity and cash market price is small with 0.0745, but is insignificant. This indicates cash market price is correlated with captive supply rather than cash market quantity. Figure I-1 shows the trend of total captive supply quantity decreased by the end of 2004, but total captive supply was increasing slowly from the beginning of 2005 to May 2008. The trend of marketing agreement quantity is similar to the trend of total captive supply since the majority of the total captive supply quantity is accounted for by marketing agreement. Forward contract gradually increased from the beginning of 2006, but packer-fed cattle shows fluctuations with no increasing or decreasing trend. Overall, a negative relationship is observed between total captive supply and cash market price in Figure I-1.

Econometric Procedure

Before conducting the Granger and the Sims tests, unit roots are tested to determine whether economic variables are stationary or nonstationary. If variables do not have unit roots, then the Granger and Sims tests can be conducted with level data. If variables have unit roots, then one can make the data stationary by taking the time-difference. If the variables are not cointegrated, then one can run the Granger and the Sims tests in the VAR with the differenced data. If the variables are cointegrated, then the Error Correction Model (ECM) needs to be introduced. The Modified Wald test is conducted without pretesting of unit root and cointegration. All variables are transformed into natural logarithms for all causality tests because the transformation tends to produce linear trends and constant variances when the variables have exponential growths and the variability of variables increase over time (Lutkepohl and Xu 2009).

Unit Root Test

The Augmented Dickey-Fuller test (ADF) is carried out to check the stationarity using a zero mean equation (1.7), a single mean equation (1.8), and a trend equation (1.9):

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=1}^{p} \phi_i \Delta y_{t-i} + e_{1t} , \tag{1.7}$$

$$\Delta y_t = \mu + \gamma y_{t-1} + \sum_{i=1}^{p} \phi_i \Delta y_{t-i} + e_{2t} , \tag{1.8}$$

$$\Delta y_t = \mu + \beta t + \gamma y_{t-1} + \sum_{i=1}^{p} \phi_i \Delta y_{t-i} + e_{3t} . \tag{1.9}$$

The ADF test starts from the estimation of the most general model given by the trend equation, (1.9) to answer a set of questions on whether $\gamma = 0$ or not. If $\gamma \neq 0$, then the variable in question has no unit root. If $\gamma = 0$, then one needs to move to the single mean equation (1.8) and test whether $\gamma = 0$ or not. If $\gamma \neq 0$ in equation (1.8), then the variable has no unit root. If $\gamma = 0$, then one moves to the zero mean equation, (1.7). If

$\gamma = 0$ in equation (1.7), this variable has a unit root. This process is the normal procedure for the ADF test.[5] The lag length p is determined by Akaike Information Criterion (AIC). Test results for unit root versus stationarity with level data are reported in table 3. The null hypotheses of unit root for marketing agreement, total captive supply, and cash market price are not rejected at the 5% significance level, while the null hypotheses of unit root for forward contract and packer-fed cattle are rejected at the 5% significance level. That is, marketing agreement, total captive supply, and cash market price are non-stationary, while forward contract and packer-fed cattle are stationary based on the ADF test. For the non-stationary variables in table I-3, ADF tests are conducted with first differenced data, and results are reported in table 4. The null hypotheses of unit root for marketing agreement, total captive supply, and cash market price are all rejected at the 5% significance levels. Therefore, these variables are stationary at first differences. Consequently, we conclude that marketing agreement, total captive supply, and cash market price are integrated order 1, I(1), while forward contract and packer-fed cattle are not integrated, I(0).

Cointegration Test

Cointegration is an econometric property of time series variables. If two or more series are themselves non-stationary, but a linear combination of them is stationary, then the series are cointegrated (Engle and Granger 1987). For the Granger and the Sims tests, if the two variables are cointegrated, then we can find the long-run relationship of the two variables using ECM. However, if they are not cointegrated, then we can run VAR models for these tests.

The econometric literature offers several different cointegration tests such as the Engle and Granger approach, the Johansen approach, and the Shin approach (Konya 2004). We apply the Johansen approach because this approach provides multiple cointegrating vectors with their respective speed of adjustment terms as a multiple equation approach, while a single equation approach gives a linear combination of the two long-run relationships (Johansen and Juselius 1990).

Because marketing agreement, total captive supply, and cash market price have unit root, while forward contract and packer-fed cattle have no unit root, two cointegration tests need to be conducted: marketing agreement vs. cash market price and total captive supply vs. cash market price. Two VAR models with four time lags are tested to determine the numbers (r) of long-run stationary relationships. The lag length is selected based on AIC. In table I-5, the trace-test statistics on the rank indicate that both marketing agreement versus cash market price and total captive supply versus cash market price models have no cointegrating vectors ($r = 0$). Therefore, we can conclude that marketing agreement and total captive supply are not cointegrated with cash market price during the data period.

Another important task in testing the causality between captive supply and cash market price is to take into account the existence of time-lag between decision of captive supplies and their actual delivery. As discussed earlier, the quantity of captive supplies is usually determined by feeders two weeks and one or two weeks before they are delivered under the marketing agreement and forward contract, respectively (Schroeter and Azzam 2004). The quantity of packer-fed cattle is totally dependent on the packer’s decision. Since the vast majority of captive supply comes from marketing agreement (76%), we conduct all causality tests with a two week lag for each captive supply method and total captive supply.

Empirical Results

The Granger and the Sims tests were conducted for the causal relationship between cash market price and total captive supply and between cash market price and marketing contract and cash market price and between packer-fed cattle and cash market price because forward contract and packer-fed cattle are integrated of order 0, while cash market price is integrated of order 1. Since the two sets of series (cash market price and forward contract, and cash market price and packer-fed cattle) are differently integrated, the causality test would provide meaningless results in the VAR model. For the Granger test, three week time lags (i.e., n and m are 3 in equations (1.1) and (1.2)) are chosen based on AIC for both sets of series: cash market price and marketing agreement, cash market price and total captive supply, and the results are reported in table I-6. In table I-6, the null hypothesis that cash market price does not cause marketing agreement is not rejected, while the null hypothesis that marketing agreement does not cause cash market price is rejected at the 5% level. Therefore, we can conclude that marketing agreement causes cash market price, but cash market price does not cause marketing agreement. For the relationship between total captive supply and cash market price, the null hypothesis that cash market price does not cause total captive supply is not rejected, while the null hypothesis that total captive supply does not cause cash market price is rejected at the 5% level. The test result suggests that total captive supply causes cash market price, but cash market price does not cause total captive supply.

The AIC also suggests that three-week time lags are most appropriate for both past values and future values for the Sims tests (i.e., n, m, and k are 3 in equations (1.3) and (1.4)). Results from the Sims tests are reported in table I-7. The Sims tests also show that marketing agreement and total captive supply cause cash market price, but cash market price does not cause marketing agreement or total captive supply.

Because the Modified Wald test does not require any pretests for unit root and cointegration, four VAR models are tested: market agreement and cash market price, forward contract and cash market price, packer-fed cattle and cash market price, and total captive supply and cash market price. From equations (1.5) and (1.6), time lags are chosen using AIC and are 3, 3, 2, and 3 (i.e., n and m are 3, 3, 2, and 3 in equations (1.5) and (1.6)) for causality tests between market agreement and cash market price, between forward contract and cash market price, between packer-fed cattle and cash market price, and between total captive supply and cash market price, respectively. In equations (1.5) and (1.6), the highest order of integration suspected in the system, d, should equal 1 for all models since marketing agreement, total captive supply, and cash market price are integrated of order 1, I(1). Therefore, the augmented lag levels, $n + d$ and $m + d$ for the VAR models of cash market price with marketing agreement, forward contract, packer-fed cattle, and total captive supply should be 4, 4, 3, and 4, respectively.

Table I-8 reports the results of the Modified Wald tests. For the causality between marketing agreement and cash market price, the null hypothesis that cash market price does not cause marketing agreement is not rejected, while the null hypothesis that marketing agreement does not cause cash market price is rejected at the 5% level. The hypothesis test indicates that marketing agreement causes cash market price. For the relationship between total captive supply and cash market price, the null hypothesis that cash market price does not cause total captive supply is not rejected while the null hypothesis that total captive supply does not cause cash market price is rejected at the 5% level. The test suggests total captive supply causes cash market price. Therefore, the results of the Modified Wald tests for the causal directions between marketing agreement and total captive supply are consistent with those of the Granger and Sims tests. However, when the Modified Wald test is applied for the relationship between forward contract and cash market price, the null hypothesis that cash market price does not cause forward contract is rejected, while the null hypothesis that forward contract does not cause cash market price is also rejected at the 5% level. Forward contract shows bidirectional causal relationship with cash market price. For the relationship between packer-fed cattle and cash market price, both null hypotheses that cash market price does not cause packer-fed cattle and that packer-fed cattle does not cause cash market price are not rejected at the 5% level. The test result suggests no causal relationship between packer-fed cattle and cash market price.

Causality test results reported in tables I-6 to I-8 are summarized in table I-9. All three tests indicate that marketing agreement and total captive supply cause cash market price. Forward contract and cash market price show bidirectional causal relationship from the Modified Wald test. However, the Modified Wald test finds no causal relationship between packer-fed cattle and cash market price.[6]

Conclusions

One of controversial debates in the cattle procurement market is about the negative relationship between cash market price and captive supply. Some researchers claim the negative relationship is an indication of packers' use of captive supply in lowering cash market price, while others claim it is merely a result of feeders' use of previous cash market price as expected price in the future for their determination of delivery time. The two different arguments were effectively used in the case of Pickett vs. Tyson Fresh Meats for plaintiff and dependant, respectively, and led two alternative specifications: price and quantity dependent models in the literature.

This study directly tests the causal direction between captive supply and cash market price using three causality tests: the Granger test, the Sims test, and the Modified Wald test. All three tests indicate that cash market price is caused by marketing agreement and total captive supply. The Modified Wald test shows the bidirectional causality between cash market price and forward contract. This test finds no causal relationship between cash price and packer-fed cattle. The Granger and the Sims tests were not conducted for forward contract and packer-fed cattle because quantity and price series are differently integrated. Overall test results indicate that captive supply causes cash market price, and the results favor the price dependent model over the quantity dependent model.

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Notes

1. The definition of captive supply by USDA Grain Inspection, Packers and Stockyards Administration (GIPSA) includes animals procured through forward contracts, marketing agreements, and packer feeding arrangements or otherwise committed to a packer more than 14 days prior to slaughter.
2. For more detail, see Ward et al. (1996): p. 3.
3. The Likelihood ratio (LR) test and Lagrange multiplier (LM) test can be used, but the Wald test is used in this study because the Wald test is usually more powerful and valid in small samples with linear hypothesis and linear model. For more detail, see Greene (2008): p. 498-504.
4. We use an aggregated data of five regions because the cattle procurement market is national in scope, and all of the U.S. geographic fed cattle price reporting regions are reasonably well linked into a national fed cattle market. For example, some cattle are shipped over 1,000 miles to slaughter (Hayenga, Koontz, and Shroeder 1996; Muth and Wohlgenant 1998).
5. For more detail, see Asteriou and Hall (2007): p. 297-298.
6. We also conducted the three causality tests with a one-week lag for the relationship between total captive supply and cash market price because of the possibility of one-week lag due to forward contract and packer-fed cattle. All three tests show the same causality direction as the one with a two-week lag. However, when the Modified Wald test was conducted for the causality between forward contract and cash market price with a one-week lag, the test found that cash market price causes forward contract. The Modified Wald test

with a one-week lag found no causal relationship between packer-fed cattle and cash market price, which is the same result as the test result with a two-week lag.

Table I-1. Descriptive Statistics of Variables

Variable	Cash Market Price ($/cwt)	Total Procured Cattle (Head)	Total Captive Supply (Head)	Marketing Agreement (Head)	Forward Contract (Head)	Packer-Fed Cattle (Head)
Mean	82.98	403,759	214,856	164,752	22,489	27,614
S.D.	9.96	63,631	48,432	47,414	13,327	7,343

Table I-2. Correlation Coefficients between Captive Supplies and Cash Market Price

Variable	Cash Market Price	Marketing Agreement	Forward Contract	Packer-Fed Cattle	Total Captive Supply	Cash Market Quantity
Cash Market Price	1.0000					
Marketing Agreement	-0.7193 < .0001	1.0000				
Forward Contract	0.3656 <.0001	-0.1027 0.0547	1.0000			
Packer-Fed Cattle	-0.1186 0.0268	0.1092 0.0409	-0.2352 < .0001	1.0000		
Total Captive Supply	-0.6225 < .0001	0.9523 < .0001	0.1353 0.0112	0.2019 0.0001	1.0000	
Cash Market Quantity	0.0745 0.1648	-0.1313 0.0141	-0.1894 0.0004	0.0297 0.5806	-0.1723 0.0012	1.0000

Table I-3. Results of Augmented Dickey-Fuller Unit Root Tests at Levels

Variable	Unit Root	Type	Lags	Tau	Pr < Tau	F	Pr > F
Marketing Agreement	Yes	Zero Mean	4	-0.33	0.5673		
		Single Mean	4	-2.13	0.2337	2.30	0.4812
		Trend	4	-1.90	0.6555	2.26	0.7246
Forward Contract	No	Zero Mean	4	0.05	0.6985		
		Single Mean	4	-4.76	0.0001	11.37	0.0010
		Trend	4	-6.06	<.0001	18.39	0.0010
Packer-Fed Cattle	No	Zero Mean	3	-0.21	0.6109		
		Single Mean	3	-4.71	0.0002	11.09	0.0010
		Trend	3	-4.74	0.0007	11.27	0.0010
Total Captive Supply	Yes	Zero Mean	4	-0.20	0.6145		
		Single Mean	4	-2.44	0.1313	2.99	0.3044
		Trend	4	-2.26	0.4565	2.97	0.5814
Cash Market Price	Yes	Zero Mean	3	0.58	0.8412		
		Single Mean	3	-1.94	0.3129	2.09	0.5367
		Trend	3	-2.96	0.1455	4.39	0.2961

Table I-4. Results of Augmented Dickey-Fuller Unit Root Tests at First Differences

Variable	Unit Root	Type	Lags	Tau	Pr < Tau	F	Pr > F
Marketing Agreement	No	Zero Mean	3	-12.64	<.0001		
		Single Mean	3	-12.63	<.0001	79.75	0.0010
		Trend	3	-12.66	<.0001	80.19	0.0010
Total Captive Supply	No	Zero Mean	3	-13.15	<.0001		
		Single Mean	3	-13.13	<.0001	86.21	0.0010
		Trend	3	-13.16	<.0001	86.59	0.0010
Cash Market Price	No	Zero Mean	2	-11.15	<.0001		
		Single Mean	2	-11.16	<.0001	62.31	0.0010
		Trend	2	-11.15	<.0001	62.13	0.0010

Table I-5. Results of Cointegration Rank Tests Using Trace Statistics

Variable vs. Cash Market Price	H0: Rank=r	H1: Rank>r	Eigen value	Trace	5% Critical Value	Results
Marketing Agreement	0	0	0.0348	17.8045	19.99	No CI
	1	1	0.0160	5.5671	9.13	
Total Captive Supply	0	0	0.0367	18.5381	19.99	No CI
	1	1	0.0162	5.6368	9.13	

Note: "No CI" means that two time series are not cointegrated.

Table I-6. Results of the Granger Tests

Null hypothesis (H0)	DF	Chi-Square	Pr>Chi-Square	Results
CP does not cause MA	3	5.96	0.1137	Not rejected
MA does not cause CP	3	13.21	0.0042	Rejected
CP does not cause CS	3	2.01	0.5712	Not rejected
CS does not cause CP	3	18.61	0.0003	Rejected

Note: CP is cash market price, MA is marketing agreement, and CS is total captive supply.

Table I-7. Results of the Sims Tests

Null hypothesis (H0)	DF	Chi-Square	5% Critical Value	Results
CP does not cause MA	3	3.3777	7.8147	Not rejected
MA does not cause CP	3	17.8351	7.8147	Rejected
CP does not cause CS	3	1.1876	7.8147	Not rejected
CS does not cause CP	3	25.0743	7.8147	Rejected

Note: CP is cash market price, MA is marketing agreement, and CS is total captive supply.

Table I-8. Results of the Modified Wald Tests

Null hypothesis (H0)	DF	Chi-Square	Pr>Chi-Square	Results
CP does not cause MA	4	6.73	0.1510	Not rejected
MA does not cause CP	4	20.36	0.0004	Rejected
CP does not cause FW	4	15.05	0.0046	Rejected
FW does not cause CP	4	17.02	0.0019	Rejected
CP does not cause PK	3	1.53	0.6754	Not rejected
PK does not cause CP	3	3.53	0.3171	Not rejected
CP does not cause CS	4	2.48	0.6477	Not rejected
CS does not cause CP	4	25.87	0.0001	Rejected

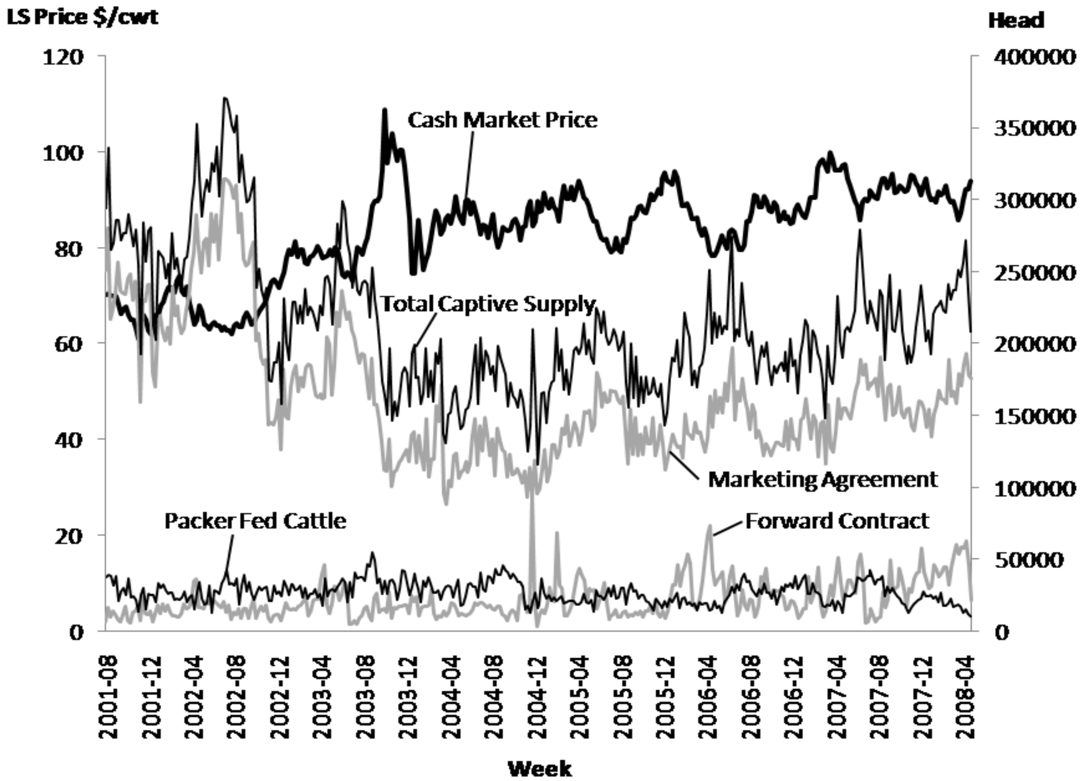
Note: CP is cash market price, MA is marketing agreement, FW is forward contract, PK is packer-fed cattle, and CS is total captive supply.

Table I-9. Summary of Three Causality Tests

Variables vs Cash Market Price	Granger Test	Sims Test	Modified Wald Test
Marketing Agreement	MA→CP	MA→CP	MA→CP
Forward Contract			FW↔CP
Packer-Fed Cattle			PK ? CP
Total Captive Supply	CS→CP	CS→CP	CS→CP

Note: CP is cash market price, MA is marketing agreement, FW is forward contract, PK is packer-fed cattle, and CS is total captive supply.
MA→CP means marketing agreement cause cash market price, FW↔CP means bidirectional causal relationship, and ? means the causal relationship cannot be found.

Figure I-1. Weekly Captive Supplies and Cash Market Prices, August 2001 to May 2008



ESSAY II

DYNAMIC ASSESSMENT OF OLIGOPOLY, OLIGOPSONY POWER, AND COST EFFICIENCY IN THE U.S. BEEF PACKING INDUSTRY

Introduction

In recent years, concentration and captive supply have been two of the most controversial issues in the literature of market power in the U.S. beef packing industry. A wave of horizontal and vertical integrations in the beef packing industry began in the late 1970's and has continued into the present market (Azzam 1997). The four-firm concentration ratio based on steer and heifer slaughter increased from 35.7 percent in 1980 to 83.2 percent in 2003, while the ratio based on boxed beef supply increased from 52.9 percent in 1980 to 84.7 percent in 2000. Most recently, after JBS purchased Swift & Co. in 2007 and JBS/Swift acquired Smithfield in 2009, the concentration ratio is expected to reach higher than ever. As a form of backward integration by packers, captive supply has also continuously increased over the last two decades.[1] The captive supply ratio as a total of cattle slaughter increased from 20.5 percent in 1988 to 44.4 percent in 2002 (USDA[c]).

As the horizontal merger continues and, as a result, the industry concentration increases in the beef packing industry, one important and interesting question is whether cost efficiency gains from increased concentration outweigh potential market power effects. As the captive supply ratio continuously increases, also disputable is whether captive supply increases the efficiency by reducing transaction costs and market risk or if it reduces competition and increases packers' market power. However, few studies examine these two issues together in the economic analysis of market power in the U.S. beef processing industry. This study considers these two issues, concentration and captive supply, simultaneously in a model that can measure oligopoly and oligopsony market powers together. This model estimates marginal effects of concentration and captive supply on beef and cattle prices to answer a question, "Do horizontal and vertical integrations (merger and captive supply) in the beef packing industry increase social welfare by achieving economies of scale and reducing transaction costs?" This model is also developed to examine changing marginal effects over the sample period. With a few exceptions (Appelbaum 1982; Schroeter 1988; Mei and Sun 2008), most previous studies in the literature assume that the conjectural variation is constant throughout the sample period. Therefore, they have limited explanations about how market power changes with evolving industry structure over time. Conjectural variations in the literature typically measure the overall market reaction to an individual firm's changes in output supply and input demand (Dickson 1981).

The objectives of this paper are threefold. First, oligopoly and oligopsony market powers for the U.S. beef retail market and cattle procurement market are estimated using the new empirical industrial organization (NEIO) model. In the modeling, oligopsony market power for the captive supply market is separated from oligopsony market power for the cash market. Second, the marginal effects of market power and cost efficiency from increasing concentration and captive supply are measured to look into the impacts on packers' margin. Finally, by adopting a time varying model, the changes of market power with changing market structure are estimated for the 1990-2006 time period with monthly data.

Results show the presence of market power in both beef retail and cattle procurement markets. Oligopsony market power is greater and fluctuated more than the oligopoly market power for the entire sample period. Concentration and captive supply have a role in increasing market power as sources of market power in both markets. Merger benefits packers more in the beef retail market than in the cattle procurement market because the marginal effect of oligopoly market power on packer's margin is greater than the marginal effect of oligopsony market power. Similar to the results of many previous studies, the current study also finds that the cost efficiency effects of increasing concentration and captive supply outweigh the market power effects.

Literature Review

Many researchers have used the NEIO framework to investigate market power issues in agricultural industries and some researchers provide reviews of these studies (Sexton 2000; Sheldon and Sperling 2002; Whitley 2003). Among the articles that use the NEIO approach, a few studies compare market power effects versus cost efficiency effects from increased concentration in agricultural and food industries. Most industrial organization literature suggests that a merger's efficiency gain offsets consumers' or producers' potential welfare losses (Azzam and Schroeter 1995; Azzam 1997; Tostao and Chung 2005). Azzam and Schroeter (1995) model the tradeoff between regional oligopsony power and cost efficiency that results from consolidation in the beef packing industry. They find the anticompetitive effects of consolidation are about half the actual cost savings from scale economies. Azzam (1997) models concentration as an explanatory variable in the margin equation for the cattle input market to estimate the concentration effect on the market power effect and the cost-efficiency effect for the U.S. beef packing industry. He finds the cost efficiency effect outweighs the oligopsony market power effect. Tostao and Chung (2005) model a bilateral oligopoly model to measure the effect of increased concentration on industry market power and cost efficiency. They also find cost efficiency gains dominate potential oligopoly market power effects from increased concentration in the U.S. wholesale beef industry. However, Lopez, Azzam, and Espana (2002) find that oligopoly market power effects dominate cost efficiency effects in the meat packing industry. They extend Azzam's framework (1997) to oligopoly markets for 32 U.S. food industries, and find that market power effects dominate cost efficiency effects in most food industries and suggest that further increases in concentration would increase output price.

Numerous studies are concerned with captive supply, primarily focusing on the relationship between the captive supply and the cash market price to investigate the effect of captive supply on the cattle procurement market. Many studies report a negative relationship between captive supply and cash market price (Elam 1992; Schroeder et al. 1993; Ward, et al. 1996; Ward, Koontz, and Schroeder 1998; Schroeter and Azzam 2004). Also, most researchers believe that this negative relationship reflects the market power of the packer as a buyer who uses the captive supply to suppress the cash market price in the cattle procurement market (Schroeder, et al. 1993; Ward, Koontz, and Schroeder 1998;

Zhang and Sexton 2000). These studies usually use an ad-hoc model to look into the relationship between captive supply and cash market price rather than use the theoretically based NEIO model to analyze the effect of captive supply as a source of market power in the industrial level. Only one study, for the U.S. pork packing industry, deals with captive supply using a NEIO model to measure market power (Zheng and Vukina 2009). They find that oligopsony market power exists in spot markets, but they do not find captive supply as a source of market power. They conclude that the market power is most likely due to concentration.

Few studies estimate the change of market power across time (Appelbaum 1982; Schroeter 1988; Mei and Sun 2008). Appelbaum (1982) estimates the conjectural elasticities and oligopoly market powers for the rubber, textile, electrical machinery, and tobacco industries from 1947 to 1971. He finds the first two industries show competitive behavior and the last two show oligopolistic behavior. Schroeter (1988) estimates the conjectural elasticities for the beef packing industry from 1951 to 1983 and finds small but statistically significant oligopoly/oligopsony price distortions in that industry. Mei and Sun (2008) estimate oligopoly and oligopsony market power for the U.S. paper industry from 1955 to 2003, and find significant market power. Recently, Crespi, Xia, and Jones (2010) model the relationship between market power and cattle cycle. They find market power is affected by the cattle cycle, and the change of market power has the same trend with cattle cycle.

The present study extends the existing literature of market power in the U.S. beef packing industry in two ways. First, the study considers captive supply as a potential source of market power in the NEIO framework. Second, the study investigates dynamic changes of both oligopoly and oligopsony powers over the past several decades. Therefore, a newly developed NEIO model considers concentration and captive supply as potential sources of market power, and the effects of market power and cost efficiency are estimated in both static and dynamic frameworks.

The Model

Generally two approaches in developing theoretical framework of conjectural elasticity occur in the literature. One is the primal production function-based approach (Azzam and Pagoulatos 1990; Mei and Sun 2008), and the other is the dual approach based on a cost function (Schroeter 1988; Azzam 1997; Lopez, Azzam, and Espana 2002; Tostao and Chung 2005). In this paper, the dual approach is used because of an absence of quantity data for the output and input at the firm level.

Following Schroeter (1988), beef processors and retailers are integrated in a single "processing-retailing" sector that is allowed to have oligopoly and oligopsony market powers simultaneously. A beef processing-retailing industry consists of N firms converting a single farm input, cattle, into a final output, beef. As indicated earlier, two procurement channels, cash market and captive supply, are considered in this study. The captive supply for each period is given because the captive supply is determined before a packer decides the amount of cattle procured from the cash market. Therefore, the firms determine the cattle procured from the cash market to maximize the firm's profit. A competitive market is assumed when farmers sell their cattle to packers, i.e. farmers are price takers. Each firm's processing technology is characterized by fixed proportions between the farm input and the output (Schroeter 1988; Azzam 1997). Conversion of the farm input into output requires non-farm inputs that are purchased in competitive markets. Each "processing-retailing" firm is not necessarily a price-taker both in the cattle procurement market and in the beef retail market.

Profit, π_i, for the i th "processing-retailing" firm (for $i = 1, 2, \ldots, N$) is maximized as:

(2.1) $$\underset{q_{1i}}{Max} \ \pi_i = P(Q)(q_{1i} + q_{2i}) - W_1(Q_1)q_{1i} - W_2(W_1(Q_1))q_{2i} - C_i(q_i, \mathbf{v}),$$

where P is the beef retail price, W_1 is the cash market cattle input price, W_2 is the captive supply cattle input price, q_{1i} is the i th firm's beef product or cattle input from the cash market, q_{2i} is the i th firm's beef product or cattle input from the captive supply, $q_i = q_{1i} + q_{2i}$ is the i th firm's total beef product or total cattle input, $Q = \sum_i^N q_i$ is the industry's total beef product or total cattle input, $Q_1 = \sum_i^N q_{1i}$ and $Q_2 = \sum_i^N q_{2i}$ are the industry's beef product or cattle input from cash market and captive supply, respectively, $C_i(q_i, \mathbf{v})$ is the processing cost function for the i th firm, and $\mathbf{v}$ is a vector of prices of non-farm inputs. The first order condition for profit maximization is:

(2.2) $$\frac{\partial \pi_i}{\partial q_{1i}} = P - W_1 + \left(\frac{\partial P}{\partial Q}\frac{\partial Q}{\partial q_{1i}}\right)(q_{1i} + q_{2i}) - \frac{\partial W_1}{\partial Q_1}\frac{\partial Q_1}{\partial q_{1i}}q_{1i} - \frac{\partial W_2}{\partial W_1}\frac{\partial W_1}{\partial Q_1}\frac{\partial Q_1}{\partial q_{1i}}q_{2i} - c_i(q_i, \mathbf{v}) = 0.$$

Rearranging the first order condition and re-writing in an elasticity form yields:

(2.3) $$M_i = -\frac{(1+\phi_i)}{\varepsilon_d}s_i + \frac{(1+\phi_i)}{\varepsilon_s}s_i + \frac{\eta(1+\phi_i)}{\varepsilon_s}\frac{q_{2i}}{q_{1i}}s_i + c_i(q_i, \mathbf{v}),$$

where M_i is the i th firm's margin, $P - W_1$, $(1+\phi_i) = \dfrac{\partial Q}{\partial q_{1i}} = \dfrac{\partial Q_1}{\partial q_{1i}}$, $\phi_i = \partial \sum_{h \neq i}^n q_{1h} \big/ \partial q_{1i}$ is the i th firm's conjecture about rivals' responses to a change in cattle purchases or in final product sales in the cash market, $\varepsilon_d = (\partial Q/\partial P)(1/Q)$ and $\varepsilon_s = (\partial Q_1/\partial W_1)(1/Q_1)$ are semi-price elasticities of retail demand and semi-price elasticities of farm supply for the cash market, respectively, $\eta = \frac{\partial W_2}{\partial W_1}$ is the change of the captive supply price with respect to the change of cash market price, $s_i = q_i/Q$ is the i th firm's market share in the retail market and the cattle procurement market, and $c_i(q_i, \mathbf{v}) = \partial C(q_i, \mathbf{v})/\partial q_{1i}$ is the marginal cost for the i th firm.

Following Azzam (1997), the i th firm's cost function is assumed to take the generalized Leontief form:

$$C_i(q_i, \mathbf{v}) = q_i \sum_k \sum_j \alpha_{kj}(v_k v_j)^{1/2} + (q_i)^2 \sum_j \beta_j v_j \,, \tag{2.4}$$

where v_j and v_k are the input price of labor, capital, and material. Rewriting equation (2.3) using a generalized Leontief cost function specified in equation (2.4) becomes:

$$M_i = -\frac{(1+\phi_i)}{\varepsilon_d} s_i + \frac{(1+\phi_i)}{\varepsilon_s} s_i + \frac{\eta(1+\phi_i)}{\varepsilon_s} \frac{q_{2i}}{q_{1i}} s_i + \sum_k \sum_j \alpha_{kj}(v_k v_j)^{1/2} + 2q_i \sum_j \beta_j v_j \,. \tag{2.5}$$

Multiplying (2.5) by each firm's market share, s_i, and summing across all n firms in the industry yields:

$$\begin{aligned} \sum\nolimits_i^n s_i M_i = {} & -\sum\nolimits_i^n s_i \frac{(1+\phi_i)}{\varepsilon_d} s_i + \sum\nolimits_i^n s_i \frac{(1+\phi_i)}{\varepsilon_s} s_i + \sum\nolimits_i^n s_i \frac{\eta(1+\phi_i)}{\varepsilon_s} \frac{q_{2i}}{q_{1i}} s_i \\ & + \sum\nolimits_i^n s_i \left(\sum_k \sum_j \alpha_{kl}(v_k v_j)^{1/2} + 2q_i \sum_j \beta_j v_j \right) \cdot \end{aligned} \tag{2.6}$$

Rearranging equation (2.6) yields the industry pricing equation as:

$$M = -\frac{(1+\Phi)H}{\varepsilon_d} + \frac{(1+\Phi)H}{\varepsilon_s} + \frac{\eta(1+\Phi)H}{\varepsilon_s} \frac{Q_2}{Q_1} + \sum_k \sum_j \alpha_{kj}(v_k v_j)^{1/2} + 2HQ \sum_j \beta_j v_j + e_m \,, \tag{2.7}$$

where M is the market-share weighted average margin for the beef packing industry, $H = \sum_i (s_i)^2$ is the Herfindahl-Hirschman Index in the retail beef market and in the cattle procurement market, $\Phi = \sum_i (q_{1i})^2 \phi_i \Big/ \sum_i (q_{1i})^2$ is the market-share weighted average conjectural variation in the retail output market and in the farm input market, and e_m is the error term for the margin equation (Cowling and Waterson 1976; Dickson 1981; Azzam 1997).

In equation (2.7), the first three terms in the right-hand side capture mark-up in the beef retail market, mark-down in the cash cattle procurement market, and mark-down in the captive supply market, respectively. The fourth term is the market-share weighted average marginal cost for the integrated processing/retailing sector. The value of $\Phi = -1$ means no mark-up or mark-down occurs. In this case all firms are price-takers in the beef retail market and in the cattle procurement market, and therefore the output price or the farm-input price is unchanged. The value of $\Phi = 0$ implies Cournot monopoly and monopsony. For noncompetitive conduct, concentration affects all mark-up, mark-down, and marginal costs in equation (2.7). Appelbaum (1982) defines conjectural variation elasticity as $\Phi^* = (1+\Phi)H$, which ranges between 0 and 1. The price elasticity of demand for the beef market and the price elasticity of supply for the cash cattle market are given by $E_d = \varepsilon_d P$ and $E_s = \varepsilon_s W_1$, respectively. Then, the degree of market power is defined by Lerner indices. The industry oligopoly market power is defined by $L^{retail} = -\Phi^* \big/ E_d$, and the oligopsony market power for the cash market and the captive supply are defined by $L^{cash} = \Phi^* \big/ E_s$ and $L^{captive} = \eta\,(Q_2 / Q_1)\,\Phi^* \big/ E_s$ respectively (Lopez, Azzam, and Espana 2002). The value $\Phi^* = 0$ denotes perfect competition, $\Phi^* = 1$

denotes pure monopoly or monopsony, and other values denote various degrees of oligopoly or oligopsony power with higher values of Φ^{*} denoting greater departures from perfect competition (Mei and Sun 2008).

Marginal effects of packers' margin from an increase of concentration in the processing/retailing industry can be separated into two parts: market power effects and cost efficiency effects. Differentiating equation (2.7) with respect to the Herfindahl-Hirschman Index, H, results in:

(2.8) $$\frac{\partial M}{\partial H} = -\frac{(1+\Phi)}{\varepsilon_d} + \frac{(1+\Phi)}{\varepsilon_s} + \frac{\eta(1+\Phi)}{\varepsilon_s}\frac{Q_2}{Q_1} + 2Q\sum_j \beta_j v_j \ .$$

The first three terms in the right-hand side of equation (2.8) capture market power effects and the fourth term captures cost savings for the beef packing industry (Azzam 1997; Lopez, Azzam, and Espana 2002).

Marginal effects of captive supply on packers' margin can also be derived by differentiating equation (2.7) with respect to captive supply, Q_2, as:

(2.9) $$\frac{\partial M}{\partial Q_2} = \frac{\eta(1+\Phi)H}{\varepsilon_s}\frac{1}{Q_1} + 2H\sum_j \beta_j v_j \ .$$

The first term in the right-hand side of equation (2.9) captures the market power effect, and the second term captures cost savings by changing captive supply.

This study examines three main hypotheses. First, whether oligopoly market power and two oligopsony market powers (one from the cash market and the other from the captive supply market) in the U.S. beef packing industry equal zero or not? If these values are not zero, then the packers exert market power in the beef retail market, the cash cattle procurement market, and the captive supply market. Second, does increasing concentration and captive supply have an effect on the oligopoly and oligopsony market powers? If they have an effect on the market power, then concentration and captive supply are sources of oligopoly and/or oligopsony market powers for packers. Finally, by increasing concentration and captive supply, do the cost efficiency effects outweigh the market power effects? If the cost efficiency effects outweigh the market power effects, then an increase of concentration and captive supply in the U.S. beef packing industry will increase social welfare.

Empirical Procedures

For complete identification, the price equation, equation (2.7), needs to be estimated simultaneously with three non-farm input demand equations, the farm input (cattle) supply equation, the retail output (beef) demand equation, and the captive supply price equation. Non-farm input demands are obtained by applying Shephard's lemma on the industry level processing cost function represented by equation (2.4) as:

(2.10) $$\frac{\partial C(Q,\mathbf{v})}{\partial v_j} = Q\sum_k \alpha_{kj}\left(\frac{v_k}{v_j}\right)^{1/2} + \beta_j HQ^2,$$

which can be re-arranged as:

(2.11) $$\frac{X_j}{Q} = \sum_k \alpha_{kj}\left(\frac{v_k}{v_j}\right)^{1/2} + \beta_j HQ + e_j,$$

where X_j is the industry level derived non-farm input demand for labor, capital, and material, and e_j is the error term for the non-farm input demand function.

Cattle supply and beef demand equations take the semi-logarithmic forms, which are specified as:

(2.12) $$\ln Q_1 = \gamma_0 + \varepsilon_s W_1 + \gamma_1 P^c + \gamma_2 P^s + \gamma_3 P^a + \gamma_4 P^f + e_s,$$

(2.13) $$\ln Q = \delta_0 + \varepsilon_d P + \delta_1 P^p + \delta_2 P^b + \delta_3 I + e_d ,$$

where, as defined previously, ε_s and ε_d are the semi-price elasticity of supply for the cash market and the semi-price elasticity of demand, respectively, P^c is corn price, P^s is sorghum price, P^a is calf price, P^f is fuel price, P^p is pork price, P^b is chicken price, I is income, and e_s and e_d are error terms for supply and demand equations, respectively.

Finally, the captive supply price (W_2) is specified as a function of cash market price (W_1), cattle quantity procured through the captive supply (Q_2), the total procured cattle quantity (Q), and linear and squared time trend terms ($time$ and $time^2$). Then, the empirical model for the price of captive supply is:

(2.14) $$W_2 = \sigma_0 + \eta W_1 + \sigma_1 Q_2 + \sigma_2 Q + \sigma_3 time + \sigma_4 time^2 + e_w ,$$

where e_w is the error term. The cash market price, W_1, is included as an independent variable because the price of cattle through captive supply (marketing agreement and forward contract) is calculated using various formulas that are closely tied to cash market price (Schroeter and Azzam 2004). Data for captive supply price is not available from 1990 to 2002 before implementing the mandatory price reporting. Therefore, equation (2.14) is separately estimated to find the value, η, with the monthly data from 2003 to 2007. The result of estimation shows that η is 0.7320, and is significant at the 5% significance level.[2] This value is not much different from Zheng and Vukina (2008)'s value, 0.7835, for the U.S. pork industry.[3]

Static Estimation

Equations (2.7), (2.11), (2.12), and (2.13), which constitute a system of six equations in total are simultaneously estimated while equation (2.14) is separately estimated due to the data limitation described above: that the captive supply price data is not available from 1990 to 2002. To overcome potential endogeneity problems in the simultaneous equation estimation, an instrumental variable estimator, generalized method of moments (GMM), is employed in this study. GMM is also used because the Breushch-Godfrey Test for autocorrelation (Breusch 1978; Godfrey 1978) rejects the null hypothesis of no first-order autocorrelation on each equation's residuals. The seventeen instrumental variables included in the equation are the Herfindahl-Hirschman Index for the steer and heifer slaughter, the squared Herfindahl-Hirschman Index, the four-firm concentration ratio for cattle procurement market, the squared four-firm concentration ratio, cattle cash price, cattle price, four-firm captive supply ratio, labor price, capital price, material price, corn price, sorghum price, calves price, fuel price, pork price, chicken price, income, and time.

Dynamic Estimation

The static econometric specification discussed in the previous section can estimate only one constant market conduct parameter, Φ, for the entire sample period. The static model cannot allow possible changes of the market conduct parameter over time. However, as suggested in a few previous studies (Schroeter 1988; Azzam 1997; Lopez, Azzam, and Espana 2002; Mei and Sun 2008), the market conduct parameter can vary over time as market environment (for example, market concentration) changes.[4] To accommodate the potential varying nature of the market conduct parameter over the sample period, the market conduct parameter is modeled as a function of the Herfindahl-Hirschman Index, H, and the captive supply, Q_2, as:

(2.15) $$\Phi = c_0 + c_1 H + c_2 Q_2 .$$

Then equation (2.7) can be changed as:

(2.16)
$$M = -\frac{(1 + c_0 + c_1 H + c_2 Q_2)H}{\varepsilon_d} + \frac{(1 + c_0 + c_1 H + c_2 Q_2)H}{\varepsilon_s} + \frac{\eta(1 + c_0 + c_1 H + c_2 Q_2)H}{\varepsilon_s}\frac{Q_2}{Q_1} + \sum_k \sum_l \alpha_{kj}(v_k v_j)^{1/2} + 2HQ\sum_j \beta_j v_j .$$

Equations (2.15) and (2.16) allow the conjectural variation parameter, Φ, to not only vary over time, but also to measure change in market powers and marginal effects of concentration and captive supply on packer margin over time. Differentiating equation (2.16) with respect to the Herfindahl-Hirschman Index, H, and with respect to the captive supply, Q_2, respectively yields:

(2.17)
$$\frac{\partial M}{\partial H} = -\frac{(1 + c_0 + 2c_1 H + c_2 Q_2)}{\varepsilon_d} + \frac{(1 + c_0 + 2c_1 H + c_2 Q_2)}{\varepsilon_s} + \frac{\eta(1 + c_0 + 2c_1 H + c_2 Q_2)}{\varepsilon_s}\frac{Q_2}{Q_1} + 2Q\sum_j \beta_j v_j ,$$

(2.18)
$$\frac{\partial M}{\partial Q_2} = -\frac{c_2 H}{\varepsilon_d} + \frac{c_2 H}{\varepsilon_s} + \frac{\eta(1 + c_0 + c_1 H + 2c_2 Q_2)H}{\varepsilon_s}\frac{1}{Q_1} + 2H\sum_j \beta_j v_j .$$

Equations (2.17) and (2.18) measure concentration effects and captive supply effects on the margin of the dynamic market conduct, while equations (2.8) and (2.9) measure those of the static market conduct. In the dynamic model, the marginal effect of captive supply influence to not only the mark-down in the captive supply but also the mark-up in the retail market and mark-down in the cash market.

Equations (2.16), (2.11), (2.12), and (2.13) are estimated for the dynamic model. The dynamic conjectural variation elasticity, Φ^*, and market power parameters, L^{retail}, L^{cash}, and $L^{captive}$ can be estimated using the estimated values of c_i, Herfindahl-

Hirschman Index, captive supply, and estimated supply and demand price elasticities. For the static and dynamic model, the market power parameters, marginal effects of concentration and captive supply on margin, and their standard errors are also estimated through GMM using the MODEL Procedure in SAS 9.2.

Data

The main data set used in this study comes from the Agricultural Marketing Service (AMS), the National Agricultural Statistic Service (NASS), Grain Inspection, Packers and Stockyards Administration (GIPSA), and the Economic Research Service (ERS) of the United State Department of Agriculture (USDA). Monthly data series for 1990 to 2006 are complied for all variables listed in the empirical procedure.

The cattle slaughter quantity in total live weight, which is used as the total beef production and the total cattle input supply (due to the fixed proportion assumption) is compiled from *Livestock Slaughter Annual Summary* of NASS (USDA[d]). The cash market cattle price data is from several long-term fed cattle price data sets of the Mandatory Price Report (MPR) of AMS, which have reported the Nebraska direct fed steer price (USDA[a]). The cash market cattle price is modified by multiplying with 2.4 as a conversion factor to produce a unit of retail beef (USDA[b]). The weighted captive supply price is combined from MPR of AMS, but captive supply price data is only available from 2003 to 2007. The Herfindahl-Hirschman Index, the four-firm concentration ratio, and the four-firm captive supply ratio for the steer and heifer slaughter are compiled from annual reports from the *Packers and Stockyards Statistical Reports* (1996-2006) GIPSA (USDA[c]).

For the beef demand equation and the cattle supply equation, the retail price of beef, the retail price of pork, the wholesale price of chicken, the corn price, and the calf price are from ERS (USDA[b]). The fuel oil number 2 price is obtained from the Consumer Price Index Database of the Bureau of Labor Statistics (BLS), U.S. Department of Labor (USDL). Per capita income data is from the econstats site (http://www.econstats.com). The consumer price index for meat and the producer price index for farm products are from BLS (USDL). These two price indices are used as price deflators for beef prices and cattle prices respectively.

For the marginal cost and non-farm input demand equations, the price index and the productivity index of labor for the U.S. animal slaughtering and processing industries are obtained from the Industry Productivity and Costs Database of BLS (USDL). The price index and the productivity index of capital and material for U.S. food and other industries are obtained from the Major Sector Multifactor Productivity Index Database of BLS (USDL). The definitions and descriptive statistics of these variables are presented in table II-1.

Empirical Results

Estimation results of static and dynamic models are reported in table II-2. For the static model, all of the 20 parameter estimates are statistically significant at the 5% significance level except the parameter estimate for pork price which is statistically significant at the 10% significance level. The coefficient of conjectural variation, Φ -0.9016, is tested for pure monopoly or pure monopsony($\Phi = 0$) and also for perfect competition($\Phi = -1$). Both null hypotheses are rejected at the 1% significance level. Therefore, results indicate that oligopoly and oligopsony conducts exist in the U.S. beef packing industry. The semi-price elasticities of supply and demand are 0.005 and -0.003, respectively, and show expected signs. For the dynamic model, conjectural variation is specified as a function of the Herfindahl-Hirschman Index and captive supply, which allows one to estimate changes in conjectural elasticity, Φ^*, and market power parameters L^{retail}, L^{cash}, and $L^{captive}$ over time. The magnitude of parameter estimates and overall fitness are comparable to those from the static GMM estimation. Most of coefficients including an additional coefficient in the conjectural equations (c_2) are significant at the 5% significance level, but the coefficient for Herfindahl-Hirschman Index (c_1) is not significant. The average value of the conjectural variation, Φ -0.8735, the semi-price elasticities of supply and demand are 0.0051 and -0.003 respectively.

Using the estimates of parameters reported in table II-2, the conjectural elasticity, Φ^*, and degrees of market power: oligopoly market power, L^{retail}, oligopsony market power from the cash market, L^{cash}, and oligopsony market power from the captive supply market, $L^{captive}$, are calculated and reported in table II-3 for both static and dynamic models. For the static model, the conjectural elasticity is 0.0188, the oligopoly market power, L^{retail}, is 0.0197, the oligopsony market power from the cash market, L^{cash}, is 0.0233, and the oligopsony market power from the captive supply, $L^{captive}$, is 0.0073.[5] They are all significant at the 1% significance level. The Lerner index, 0.0197, from the retail market indicates a 1.97% mark-up in the beef price, while Lerner indices, 0.0233 and 0.0073, from the cattle procurement market suggest 2.33% and 0.73% mark-downs in the cattle price, respectively. For the dynamic model, the average value of varying conjectural elasticities is 0.0242, the average value of oligopoly market power, L^{retail}, is

0.0253, the average value of oligopsony market power for the cash market, L^{cash} , is 0.0294, and the average value of oligopsony market power for the captive supply, $L^{captive}$, is 0.0093. They are all significant at the 1% significance level. The dynamic values are slightly greater than the static values. The results imply that market power exists in both beef retail and cattle procurement markets. The oligopsony market power from captive supply is smaller than the oligopsony market power from the cash market. However, the summation of Lerner indices from captive supply and cash markets shows larger market power in the cattle procurement market than in the retail market from both static and dynamic models. These results are consistent with the findings of Tostao and Chung (2005).

Dynamic changes of market power for the U.S. beef packing industry from 1990 to 2006 are graphically illustrated in figure II-1. During the period of 1990-2006, the maximum value of oligopoly market power is 0.0284 in 2000, the minimum value is 0.0237 in 1990. The maximum value of oligopsony power is 0.0488 in 2002, and the minimum value is 0.0316 in 1990. Figure II-1 shows the oligopoly power is always smaller than the oligopsony power throughout the data period. The oligopsony power is quite fluctuating, while oligopoly power is relatively steady. The oligopsony market power from the cash market is always larger than the market power from the captive supply market. However, in recent years the market power caused by captive supply has been increasing while the market power from the cash market has been decreasing. The overall trend of oligopsony power is dominated by the market power from the cash market until 1999. However, after 1999, the overall trend of oligopsony power follows the market power trend from the captive supply market, which is perhaps due to the recent increase in captive supply in the U.S. cattle procurement market.

Marginal effects of market concentration on packer margin (retail price minus farm price) are calculated by equation (2.8) for the static model and equation (2.17) for the dynamic model and are reported in table II-4. As discussed previously, marginal effects are separated into market power and efficiency effects. The market power effects are further separated into three parts: effects from oligopoly, oligopsony from the cash market, and oligopsony from the captive supply market. From the static model, the oligopoly effect, the oligopsony effect from cash market and captive supply, and the cost efficiency effect are 33.06, 19.65, 6.18, and -198.68, respectively. The total effect is -139.78, which indicates the cost efficiency effect outweighs the market power effect. The estimated effects are all statistically significant at the 1% significance level. The results suggest that if the Herfindahl-Hirschman Index increases 0.01, then the packer margin will increase about 0.33 $/cwt by oligopoly effect, 0.20 $/cwt by oligopsony effect from cash market, 0.06 $/cwt by oligopsony effect from captive supply, respectively and will decrease by 1.99 $/cwt by cost efficiency effect, and overall the margin will decrease by 1.40 $/cwt. This result contradicts to a common belief that packers pursue merger to increase their margin. However, this result can be interpreted to show that even though their margin for a unit of product decrease, packers' total margin could be increased by increasing their total quantity and they could reinforce their potential bargaining position in the market with merger and integration.

From the dynamic model, the oligopoly effect, the oligopsony effect from cash and captive supply markets, the cost efficiency effect, and the total effect are calculated for each year. Average values of these effects are 60.12, 35.04, 11.03, -253.98, and -147.80, respectively. They are also statistically significant at the 1% significance level. This result is similar to the result of the static model. These results suggest that merger is more effective in the beef retail market than in the cattle procurement market to exercise packer's market power, and that as concentration increases, the packer margin increases in both oligopoly and oligopsony markets while cost efficiency also exists. The cost efficiency effect overwhelmingly dominates the market power effects in both static and dynamic models. This outcome is consistent with the findings of Azzam and Schroeter (1995), Azzam (1997), Sexton (2000), and Tostao and Chung (2005), but contradicts to those of Lopez, Azzam, and Espana (2002).

The marginal effects of captive supply on packers' margin are also calculated in table II-5. The oligopsony effect, the cost efficiency effect, and the total net effect are 1.11, -10.95, and -9.83, respectively, in the static model. The results indicate if the captive supply increases by 100,000 cwt, then packer margin will increase by 0.01 $/cwt due to oligopsony effect, decrease by 0.11 $/cwt due to cost efficiency effect, and decreases by 0.10 $/cwt due to total net effect, respectively. For the dynamic model, the average values for the oligopoly effect, the oligopsony effects from cash market and captive supply, the cost efficiency effect, and the total net effect are 1.08, 0.63, 2.17, -13.99, and -10.11, respectively. These values are statistically significant at the 1% significance level. These results suggest that increasing the captive supply expands the oligopsony market power, but the cost efficiency effect dominates the market power effect by increasing captive supply.

In summary, the first null hypothesis that the oligopoly market power and oligopsony market power in the U.S. beef packing industry equal zero is rejected in the static and dynamic model. Therefore, market powers are exerted in both the beef retail market and the cattle procurement market, but the oligopsony market power is larger than the oligopoly market power. Second, concentration and captive supply have an effect on oligopoly and oligopsony market power. This conclusion implies that packers use concentration and captive supply as sources of market power, but the marginal effect on market power by increasing concentration is more effective in the beef retail market than in the cattle procurement market. Finally, by increasing concentration and captive supply, the cost efficiency effect outweighs the market power effect in both the static and dynamic models. Consequently, an increase of concentration and captive supply in the U.S. beef packing industry increases social welfare.

Conclusions

During the last two decades, concentration and captive supply have been two important issues in studying market power in the U.S. beef packing industry. This paper contributes to the literature of market power in the U.S. beef packing industry in three ways. First, the oligopoly and oligopsony market powers are simultaneously considered, and the oligopsony market power is divided by two parts: cash cattle procurement market power and captive supply market power. Second, a NEIO approach developed in this study can measure the market power of retail market, cash cattle market, and captive supply based on parameter estimates of concentration and captive supply. Marginal effects of concentration and captive supply on margin can also be measured in this study. Third, the time varying model is applied to look into the dynamic change of market conducts such as conjectural elasticity and oligopoly and oligopsony market powers. The time-varying model allows one to dynamically calculate the change of market power in the U.S. beef packing industry.

The empirical results show the presence of market power in both the beef retail and the cattle procurement markets, but their magnitudes are not seriously large. Concentration and captive supply have a role as sources of market power. Especially, the market power from captive supply shows an increasing trend with an increasing portion of captive supply in the cattle procurement method. Additionally and perhaps more importantly, results show that the cost efficiency effects from the increased concentration and captive supply outweigh the market power effects in the U.S. beef packing industry.

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Notes

1. The definition of captive supply by USDA Grain Inspection, Packers and Stockyards Administration (GIPSA) includes animals procured through forward contracts, marketing agreements, and packer feeding arrangements or otherwise committed to a packer more than 14 days prior to slaughter.
2. In estimating equation (2.14), the RESET test is conducted, and results indicate that the linear model specified in equation (2.14) is appropriate with the power 2, 3, and 4 at the 5% significance level. However, the Durbin-Watson test suggests an autocorrelation problem in this model. Therefore, a GLS procedure is implemented to estimate the parameters. Results show: σ_0 = 24.3025, η = 0.7320, σ_1 = 3.9214, σ_2 = -3.4516, σ_3 = 0.2178, and σ_4 = -0.0038. All coefficients are significant at the 5% significance level.
3. Zheng and Vukina (2008) estimate elasticity of captive supply price with respect to cash market price, $\frac{\partial W_2}{\partial W_1}\frac{W_1}{W_2}$, rather than $\frac{\partial W_2}{\partial W_1}$ in the similar equation for the U.S. pork industry. The estimated elasticity from Zheng and Vukina (2008) is 0.7835 while the corresponding elasticity from our study is 0.6259.
4. Azzam (1997) and Lopez, Azzam, and Espana (2002) use time varying models to specify the conjectural variation parameter as a function of the Herfindahl-Hirschman Index. However both studies fail to reject the null hypothesis that the conjecture variation parameter is a constant. Mei and Sun (2008) modeled the conjectural variation parameter as a function of the four-firm concentration ratio and average mill capacity for the U.S. paper industry. Appelbaum (1982) modeled

the conjectural elasticity as a function of labor input price, capital input price, and material input price. Schroeter (1988) also modeled the time varying parameter of conjectural variation as a function of labor input price, capital input price, and time trend for the U.S. beef packing industry.

5. Boundaries of each Lerner index are estimated based on, $0 < L < 1/|E_{d(s)}|$. They are $0 < L^{retail} < 1.0384$, $0 < L^{cash} < 1.2422$, and $0 < L^{captive} < 0.3910$, respectively. The minimum value, 0, leads to perfect competition, and the maximum values lead to pure monopoly or pure monopsony.

Table II-1. Descriptive Statistics of Variables Used in the Empirical Estimation (1990.1-2006.12, N=204)

Variable	Symbol	Mean	S. D.	Minimum	Maximum
Herfindahl Hirschman index for steer and heifer slaughter	H	0.1912	0.0116	0.1661	0.2096
Cattle slaughter weight (bil./lbs)	Q	3.4675	0.2787	2.8087	4.1485
Retail price of beef ($/cwt)	P	317.77	48.24	271.00	431.72
Cash market price ($/cwt)	W_1	73.46	9.00	58.28	105.5
Captive supply price ($/cwt)	W_2	85.91	5.39	74.62	99.45
4 firm concentration ratio	CR	79.25	2.82	71.6	83.2
4 firm captive supply ratio	$CAPR$	28.80	10.04	10.30	52.90
Price of corn ($/bushel)	P^c	2.31	0.45	1.52	4.43
Price of sorghum ($/bushel)	P^s	2.23	0.53	1.41	4.28
Price of calves ($/cwt)	P^a	101.58	20.91	55.40	149.00
Price of fuel oil #2 ($/gallon)	P^f	1.25	0.47	0.83	2.65
Labor productivity (2000=100)	Q/X_l	100.73	3.11	95.19	109.17
Retail price of pork ($/cwt)	P^p	243.99	27.08	199.33	289.76
Whole. price of chicken ($/cwt)	P^b	37.68	11.99	16.00	66.80
Per capita income (thousand $)	I	12.40	1.30	10.47	14.61
Price of labor (2000=100)	v_l	98.27	7.79	83.50	110.39
Capital productivity (2000=100)	Q/X_c	101.45	1.73	99.53	105.59
Price of capital (2000=100)	v_c	94.51	1.72	99.53	105.59
Material productivity (2000=100)	Q/X_m	102.68	2.76	98.71	109.87
Price of material (2000=100)	v_m	101.96	9.57	87.62	121.27
PPI for farm product (2000=100)	PPI	109.54	8.63	94.77	135.78
CPI for meat (2000=100)	CPI_m	98.75	11.96	81.61	122.01
CPI for fuel (2000=100)	CPI_f	100.23	16.51	79.69	144.31

Table II-2. GMM Estimates of Parameters and Conjectural Variation from Static and Dynamic Models for the U.S. Beef Packing Industry

Parameter	Variable	Static Model	Dynamic Model
Conjectural Variation			
Φ c_0	Constant	-0.9016 (0.0294)**	-0.8380 (0.0405)**
c_1	H		-0.2742 (0.1729)
c_2	Q_2		0.0168 (0.0053)**
Supply Function			
γ_0	Constant	0.8010 (0.0510)**	0.7905 (0.0504)**
ε_S	W_1	0.0050 (0.0003)**	0.0051 (0.0003)**
γ_1	P^{corn}	0.0405 (0.0145)**	0.0416 (0.0145)**
γ_2	$P^{sorghum}$	-0.0194 (0.0056)**	-0.0189 (0.0057)**
γ_3	P^{calves}	-0.0069 (0.0004)**	-0.0069 (0.0004)**
γ_4	P^{fuel}	-0.0998 (0.0110)**	-0.1045 (0.0102)**
Demand Equation			
δ_0	Constant	1.2675 (0.0583)**	1.2755 (0.0544)**
ε_d^r	P	-0.0030 (0.0002)**	-0.0030 (0.0001)**
δ_1	P^{pork}	-0.0003 (0.0002)*	-0.0003 (0.0002)*
δ_2	$P^{chicken}$	0.0004 (0.0002)**	0.0004 (0.0002)**
δ_3	$INCOME$	0.0384 (0.0014)**	0.0379 (0.0013)**
Cost Function			
α_{ll}	$(v_l v_l)^{1/2}$	12.1328 (0.1525)**	10.4849 (0.1012)**
α_{cc}	$(v_c v_c)^{1/2}$	-8.2483 (0.1147)**	-9.8505 (0.1162)**
α_{mm}	$(v_m v_m)^{1/2}$	-3.2792 (0.0485)**	-6.1839 (0.0786)**
α_{lc}	$(v_l v_c)^{1/2}$	-2.6343 (0.0329)**	-2.9081 (0.0310)**
α_{cm}	$(v_c v_m)^{1/2}$	12.1509 (0.1545)**	14.0481 (0.1488)**
α_{ml}	$(v_m v_l)^{1/2}$	-8.8166 (0.1135)**	-7.3248 (0.0772)**
β_l	v_l	0.4401 (0.0232)**	0.7261 (0.0248)**
β_c	v_c	-1.2847 (0.0172)**	-1.3708 (0.0147)**
β_m	v_m	0.4859 (0.0208)**	0.2118 (0.0223)**

Notes: Parentheses are approximate standard errors.

* significant at the 10% significance level.

** significant at the 5% significance level.

Table II-3. Conjectural Elasticity and Market Power for the U.S. Beef Packing Industry

Market Power	Static Model	Dynamic Model
Conjectural Elasticity (Φ^*)	0.0188 (0.0056)	0.0242 (0.0058)
Oligopoly Power in Retail Market (L^{retail})	0.0197 (0.0061)	0.0253 (0.0064)
Oligopsony Power in Cash Market (L^{cash})	0.0233 (0.0069)	0.0294 (0.0068)
Oligopsony Power in Captive Supply ($L^{captive}$)	0.0073 (0.0021)	0.0093 (0.0022)

Note: Parentheses are standard errors.
All estimates are statistical significant at the 1% significance level.

Table II-4. Marginal Effects of Market Concentration on Margin for the U.S. Beef Packing Industry from 1990 to 2006

Marginal Effect	Static Model (cents/cwt)	Dynamic Model (cents/cwt)
Oligopoly	33.06 (10.171)	60.12 (13.767)
Oligopsony Cash Market	19.65 (5.8021)	35.04 (7.6204)
Oligopsony Captive Market	6.18 (1.8263)	11.03 (2.3986)
Cost Efficiency	-198.68 (18.192)	-253.98 (18.093)
Total Effect	-139.78 (10.959)	-147.80 (19.614)

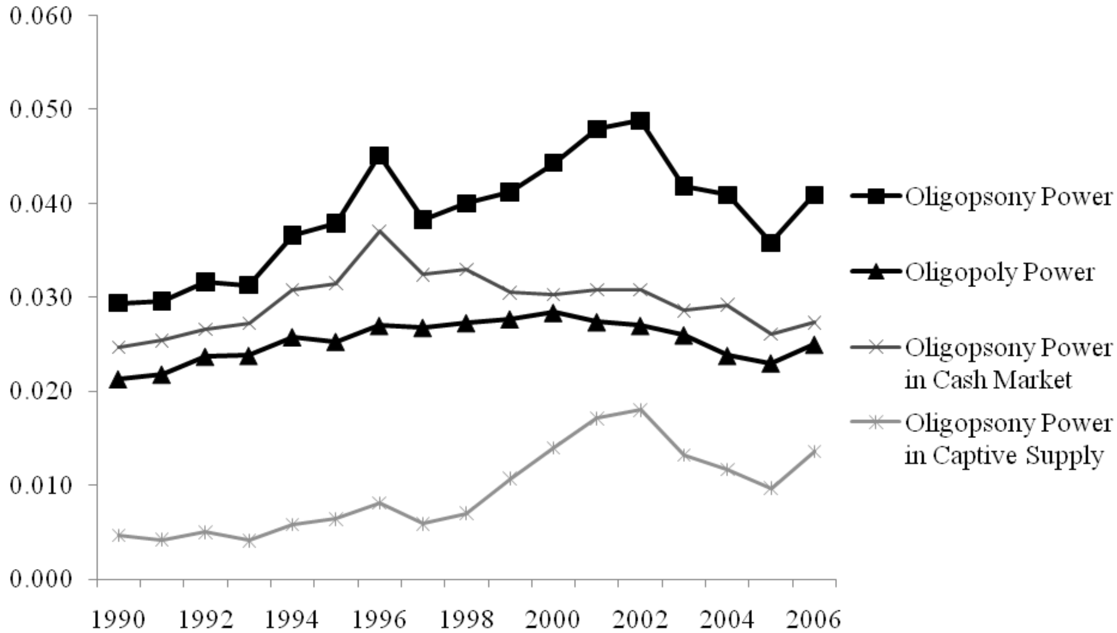
Note: Parentheses are standard errors.
All estimates are statistical significant at the 1% significance level.

Table II-5. Marginal Effects of Captive Supply on Margin for the U.S. Beef Packing Industry from 1990 to 2006

Marginal Effect	Static Model (cents/cwt)	Dynamic Model (cents/cwt)
Oligopoly	-	1.08 (0.3420)
Oligopsony Cash Market	-	0.63 (0.1991)
Oligopsony Captive Market	1.11 (0.3289)	2.17 (0.4369)
Cost Efficiency	-10.95 (1.0024)	-13.99 (0.9969)
Total Effect	-9.83 (0.7760)	-10.11 (1.0452)

Note: Parentheses are standard errors.
All estimates are statistical significant at the 1% significance level.

Figure II-1. Changes of Market Power for the U.S. Beef Packing Industry from 1990 to 2006



ESSAY III

DYNAMIC ASSESSMENT OF BERTRAND OLIOGOPSONY IN THE U.S. CATTLE PROCUREMENT MARKET

Introduction

Most studies using the new empirical industrial organization (NEIO) approach on the market power of the U.S. beef packing industry focus on the market structure, such as horizontal concentration and vertical integration, as sources of market power rather than characteristics of the market such as cattle cycle and seasonality. Also, the studies generally use the Cournot model by assuming quantity competition in the cattle procurement market.

Cattle production fluctuates unpredictably based on weather conditions and economic environment while beef demand is relatively stable and predictable. The fluctuation of cattle production leads to price fluctuation and these variations could influence the bargaining position of producers and packers in the cattle procurement market (Crespi, Xia, and Jones 2010). Therefore, the periodic fluctuation of the cattle production, cattle cycle and seasonality, could affect market power in the cattle procurement market. In addition, this fluctuation in cattle supply could make packers compete with price rather than quantity to maximize profit.

In the long-run, packers make significant production decisions based on quantity such as increasing factory size, purchasing slaughter machines or packing machines, as well as other investments. These decisions could lead to quantity competition. However, in the short-run, cattle purchase could lead to price competition (Lepore 2008). Under the condition of fixed plant capacity, if packers' cattle amount is not guaranteed in the cattle market during the short cattle supply then they would aggressively bid to obtain their optimal operation level of cattle for beef production. On the other hand, if there is enough cattle supply in the market, then packers might try to lower the cattle price under the marginal cost for cattle production. This strategy for packers is consistent with the structural conduct performance (SCP) theory (Stiegert, Azzam, and Brorsen 1993). Additionally, the reason why packers gradually increase the volume of alternative marketing arrangements (captive supply) could be explained by this view point. Packers can reduce cattle supply risk and price competition by increasing captive supply during the short cattle supply and they might be tacitly collusive to lower the cattle price during the excess cattle supply. From this perspective, the cattle cycle and seasonality may affect pricing and market power in the cattle market. It therefore stands to reason that the Bertrand model is more accurate than the Cournot model to measure the oligopsony market power for the cattle procurement market.

The objective of this paper is three fold. First, this paper provides a conceptual framework for the Bertrand model to analyze oligopsony market power and to compare the Bertrand model with the Cournot model. Second, this paper estimates the overall market power with the static model and annual market power changes with the dynamic model at national and two regional levels. Finally, the effects of concentration, cattle cycle, and seasonality on markdown for cattle price are estimated to look into how they influence on market power in the U.S. cattle procurement market.

The empirical results show that oligopsony market power exists in the cattle procurement market and that oligopsony market power is affected by cattle cycle and seasonality and, finally, that the variation of market power changes equivalently with the cattle cycle. However, concentration has a negative effect on market power in the cattle procurement market.

Concentration, Cattle cycle, and Seasonality

The concentration for cattle procurement was drastically increased during the 1980's and has stayed at high levels after 1990 (USDA). Figure III-1 shows the concentration change based on Herfindahl-Hirschman Index (HHI) for steer and heifer slaughter. The HHI was 0.0561 in 1980 but it was rapidly increased by 0.2005 in 1992, and has stayed around 0.2 until recently. The Department of Justice consider the industry to be concentrated if the HHI is greater than 0.18. Therefore, concentration has been in the middle of controversy for the market power issue in the cattle procurement market during the last three decades.

Cattle cycles are measured from one trough to the next. There are six full cycles in cattle inventories since 1928 and the average length of cattle cycles are about 10 years (Anderson, Robb, and Mintert 1996). Figure III-2 shows the cattle cycle based on cattle supply from 1980 to 2009. The fifth cycle began in 1979 and the sixth cycle began in 1990. The latest cycle began in 2004 and cattle supplies show an increasing trend.

A seasonal pattern is a regularly repeating cycle that is completed once every twelve months. Figure III-2 shows the averaged monthly changes of the slaughtered cattle supply from 1980 to 2009. The slaughtered cattle quantities are high from May to October while those from November to April are low. These cattle cycle and seasonality cycles are responsible for creating price fluctuation in the cattle market.

Literature Review

Most studies using NEIO approach use the Cournot model to analyze market power for the U.S. beef packing industry because it is easy to parameterize the conjectural elasticity, price elasticity of demand, and price elasticity of supply using simultaneous equations. Additionally, those elasticities can be used to easily calculate market power (Schroeter 1988; Azzam and Schroeter 1995; Azzam 1997; Sexton 2000; Lopez, Azzam and Espana 2002; Tostao and Chung 2005; Zheng and Vukina 2009).

There are three studies that use the Bertrand oligopsony model for the cattle market (Koontz, Garcia, and Hudson 1993; Koontz and Garcia 1997; Cai, Stiegert, and Koontz 2009). They develop the Regime-Switching model based on the dynamic non-cooperative game theoretic model. They find that the evidence of cooperative/competitive conduct among the beef packers is present, but the conduct varies across markets. They attempt to determine whether the cooperative conduct is present as evidence of market power, but they don't estimate the conduct parameters in the cattle procurement market.

Two studies are concerned with cattle supply and cattle cycle. Stiegert, Azzam, and Brorsen (1993) use the NEIO model assuming quantity competition to determine the effect of anticipated and unanticipated cattle supply on the departure of fed cattle prices from cattle's marginal value product. They find that packers follow an average processing cost (APC) pricing rule and that reducing concentration is unlikely to affect change in cattle prices predicted by SCP based studies of the industry[1]. They use anticipated and unanticipated cattle supply to look into packer's behavior, primarily how packers react to those cattle supplies. The anticipated cattle supply is specified by the cattle on feed, cattle placements, and the seasonal dummy variable. Therefore, the effects of cattle cycle and seasonality are embedded in the anticipated cattle supply. Consequently, they do not explain the effects of cattle cycle and seasonality. Crespi, Xia and Jones (2010) investigate the relationship between market power and cattle cycle with a dynamic cattle production decision model and a dynamic profit maximization model based on the Cournot model. They provide a conceptual framework for how the cattle cycle and buyer markets are related. They find that a larger cattle stock leads to a lower fed cattle price and the cattle stock's negative effect on price is magnified by the degree of buyer market power. They develop an equilibrium model that consists of the dynamic cattle supply equation for feeders and dynamic cattle demand for packers. However, they assume that the market power is determined by the number of packers rather than the packer's market conducts.

Therefore, this paper extends the traditional NEIO model in two ways. First, this paper provides how the implications of market power from the Bertrand model differ compared to the Cournot model through analytical derivation. Second, concentration in the traditional view as well as cattle cycle and seasonality for the nature of cattle market are included in modeling the market conduct equation in order to measure their effects on market power.

The Model

The two NEIO models are reviewed in this section: the Bertrand model and the Cournot model. We analyze the input market rather than output market, so we use monopsony or oligopsony as working terms instead of monopoly or oligopoly. In the Bertrand oligopsony model, buyers choose the price to pay for a unit of input, which affects the market supply. The Bertrand model predicts that a duopsony is enough to push prices up to the marginal cost level for input production. This suggests that duopsony will result in perfect competition, commonly referred to in the economics literature as the "Bertrand paradox". However, in the Cournot oligopsony model, where buyers compete strategically with their quantity, buyers enjoy positive profits as the resulting input market prices do not exceed those of the marginal costs. By imposing some assumptions in the modeling, we will demonstrate how this suggestion that duopsony will result in perfect competition in the Bertrand model could be changed.

Bertrand Model

In view of the intended application, we will focus on oligopsony market power in the cattle procurement market. Packers determine cattle price as a strategy variable to maximize their profit from the cattle procurement market while the wholesale price to sell their output, boxed beef, to the retailer is assumed as a given. The cattle supply is assumed as fixed in the short-run because feeders cannot increase their cattle supply in the short-run. Feeders cannot determine the cattle supply, but they can sell their cattle to the highest bidder in the cattle market.

In the beef processing industry it is assumed that N packers convert a single farm input, cattle, into a final output, boxed beef, with fixed proportions technology between the farm input and the output (Schroeter 1988; Azzam 1997). Conversion of the farm input into output requires non-farm inputs that are purchased in competitive markets. Profit, π_i, for the i th firm (for $i = 1, 2, \ldots, N$) is:

$$\text{(3.1)} \qquad \underset{w_i}{Max} \ \pi_i = (P - w_i)q_i(w_i, w_j(w_i)) - C_i(q_i(w_i, w_j(w_i), \mathbf{v}),$$

where P is the boxed beef wholesale price, w_i is the cattle input price for i th firm, w_j is the cattle input price for j th firm (for $j = 1, 2, \ldots, N$ and $i \neq j$), q_i is the i th firm's beef product or cattle input, $C_i(q_i, \mathbf{v})$ is the processing cost for the i th firm, and $\mathbf{v}$ is a vector of prices of non-farm inputs. The first order condition for profit maximization is:

$$\text{(3.2)} \qquad \frac{\partial \pi_i}{\partial w_i} = -q_i + (P - w_i)\left(\frac{\partial q_i}{\partial w_i} + \sum_{j \neq i} \frac{\partial q_i}{\partial w_j}\frac{\partial w_j}{\partial w_i}\right) - \frac{\partial C}{\partial q_i}\left(\frac{\partial q_i}{\partial w_i} + \sum_{j \neq i} \frac{\partial q_i}{\partial w_j}\frac{\partial w_j}{\partial w_i}\right) = 0\,.$$

Rearranging the first order condition and re-writing in elasticity form yields:

$$\text{(3.3)} \qquad q_i = (P - w_i - mc_i)\left(\varepsilon_{ii}\frac{q_i}{w_i} + \sum_{j \neq i} \varepsilon_{ij}\theta_{ji}\frac{q_i}{w_i}\right),$$

where $\varepsilon_{ii} = \dfrac{\partial q_i}{\partial w_i}\dfrac{w_i}{q_i}$ is the own price elasticity of cattle purchase for the i th firm,

$\varepsilon_{ij} = \dfrac{\partial q_i}{\partial w_j}\dfrac{w_j}{q_i}$ is the cross price elasticity for the i th firm with respect to the j th firm's

price changes, $\theta_{ji} = \dfrac{\partial w_j}{\partial w_i}\dfrac{w_i}{w_j}$ is the price conjectural elasticity of j th firm with respect to

i th firm's price change, and $mc_i = \dfrac{\partial C(q_i, \mathbf{v})}{\partial q_i}$ is the i th firm's marginal cost.

If we assume that the effect of the j th firm's price change on the i th firm's fed cattle purchase is smaller than the effect of its own price change, and firms are symmetric (Cai, Stiegert, and Koontz 2009), this means $\frac{\partial q_i}{\partial w_i}\frac{w_i}{q_i} > -\frac{\partial q_i}{\partial w_j}\frac{w_j}{q_i}$ and then we can write the ratio of own price elasticity of cattle procurement to cross price elasticity with respect to j th firm's price, as $R_i = -\left(\frac{\partial q_i}{\partial w_i}\frac{w_i}{q_i} \Big/ \frac{\partial q_i}{\partial w_j}\frac{w_j}{q_i}\right) \geq 1$. That is, $\varepsilon_{ij} = -\frac{\varepsilon_{ii}}{R_i}$, then the equation (3.3) becomes:

(3.4)
$$P - w_i = \frac{w_i}{\left(1 - \frac{\Theta_i}{R_i}\right)\varepsilon_{ii}} + mc_i,$$

where $\Theta_i = \sum_{j \neq i} \theta_{ji}$. In equilibrium, all firms have the same value Θ_i, R_i and ε_{ii}, then the industry level margin equation can be yield (Appelbaum 1982; Schroeter 1988):

(3.5)
$$P - W = \frac{1}{\left(1 - \frac{\Theta}{R}\right)\varepsilon_b} W + mc,$$

where W is the industrial level cattle price, Θ is the industrial level price conjectural elasticity, R is the industrial level ratio of own price elasticity of cattle procurement to cross price elasticity, ε_b is the own price elasticity of cattle purchase, and mc is the industrial level marginal cost.

In equation (3.5), the term in the left side is the industrial level margin for a unit of cattle, the first term on the right side is markdown for a unit of cattle in the cattle procurement market, and the second term on the right side is the marginal cost for a unit of cattle in the beef processing industry. For analyzing the short-run oligopsony power in the cattle procurement market we should look at the markdown term. The markdown is determined by three parameters: the price conjectural elasticity, the ratio of own price elasticity of cattle procurement to cross price elasticity, and the own price elasticity of cattle purchase. These three parameters show the market participant's reactions about a firm's cattle pricing change. That is, the price conjectural elasticity shows the reaction of the rival's cattle pricing, the ratio of own price elasticity of cattle procurement to cross price elasticity shows the relative effect firms' price change on a firm's cattle purchase, and the own price elasticity of cattle purchase reveals the decision of the feeder's cattle supply decision to choose who they sell their cattle to, corresponding to a firm's pricing change.

The own price elasticity of cattle purchase, ε_b, is an infinite in the traditional view of the Bertrand model so that the market will reflect perfect competition with no markdown in the industry.[2] In reality, however, there are some restrictions like capacity constraints. If a single firm does not have the capacity to procure the whole cattle market then the "price equals marginal cost" result may not hold. Thus, the range of the own price elasticity of cattle purchase will be $0 < \varepsilon_b < \infty$. This reflects that the "Bertrand paradox" can be fixed if the own price elasticity of cattle purchase is quite smaller than the infinite. The own price elasticity of cattle purchase is usually greater than the price elasticity of cattle supply, $\varepsilon_c = \frac{\partial Q}{\partial W}\frac{W}{Q}$ (Anderson, Palma, and Kreider 2001).

For the market conduct in equation (3.5), when $\varepsilon_b = \infty$, the market will be perfect competition. When $0 < \varepsilon_b < \infty$, the market will be oligopsony or monopsony. Under this assumption, $0 < \varepsilon_b < \infty$, market conduct depends on the price conjectural elasticity, Θ.

$\Theta = 0$ means Bertrand-Nash when $N > 1$ and pure monopsony when $N = 1$. $\Theta = 1$ means cartel or symmetry among the firms and $0 < \Theta < R$ means oligopsony.[3]

Cournot Model

Alternatively, in the Cournot model packers determine cattle quantities as a strategy variable to procure the cattle from the cattle procurement market and feeders determine the cattle supply to the cattle procurement market. Finally, cattle price is determined in the market by cattle supply and demand. That is, the fixed supply assumption is released by long-run decision making for feeders and the feeders face a competitive market for selling their cattle to packers. Under the same assumption of the fixed proportions technology, then i th firm's profit is:

(3.6) $$\underset{q_i}{Max}\ \pi_i = \left(P - W(Q)\right)q_i - C_i(q_i, \mathbf{v}),$$

where P is the beef wholesale price, W is the cattle price in the market level, and q_i is the i th firm's cattle or boxed beef quantity. The first order condition for profit maximization is:

(3.7) $$\frac{\partial \pi_i}{\partial q_i} = P - W - \frac{\partial W}{\partial Q}\frac{\partial Q}{\partial q_i} q_i - \frac{\partial C_i(q_i, \mathbf{v})}{\partial q_i} = 0 .$$

Rearranging the first order condition and re-writing in elasticity form yields:

(3.8) $$P - W = \frac{\phi_i}{\varepsilon_c} W + mc_i ,$$

where $\phi_i = \frac{\partial Q}{\partial q_i}\frac{q_i}{Q}$, is the i th firm's quantity conjectural elasticity and $\varepsilon_c = \frac{\partial Q}{\partial W}\frac{W}{Q}$ is the price elasticity of cattle supply in the cattle procurement market. In equilibrium, all firms have the same value ϕ_i, then the industry level margin equation can be written (Appelbaum 1982; Schroeter 1988):

$$P - W = \frac{\Phi}{\varepsilon_c} W + mc \,. \tag{3.9}$$

In the Cournot model, markdown consists of the quantity conjectural elasticity, Φ, and the cattle supply elasticity, ε_c. The range of conjectural elasticity is between 0 and 1. The value $\Phi = 0$ means perfect competition and $\Phi = 1$ means pure monopsony, and other values mean various degrees of oligopsony power with higher values of Φ denoting greater oligopsony (Appelbaum 1982). The price elasticity of cattle supply, ε_c, is considered as $0 < \varepsilon_c < 1$ because price elasticity of supply for agricultural markets are usually inelastic and positive.

Empirical Procedures

For econometric estimation, we assume a generalized Leontief cost function (Diewert 1974; Schroeter 1988) for the beef processing industry:

$$C(Q, \mathbf{v}) = Q \sum_k \sum_j \alpha_{kj} (v_k v_j)^{1/2} + \sum_j \beta_j v_j \,, \tag{3.10}$$

where v_j and v_k are the input price of labor, capital, and material. Then the industrial level marginal processing cost function is given by:

$$mc = \sum_k \sum_j \alpha_{kj} (v_k v_j)^{1/2} \,, \tag{3.11}$$

by substituting equation (3.11) into equation (3.5), we obtain the industrial level Bertrand margin equation:

(3.12) $$P - W = \frac{1}{\left(1 - \frac{\Theta}{R}\right)\varepsilon_b} W + \sum_k \sum_j \alpha_{kj} (v_k v_j)^{1/2} + e_b ,$$

where $\frac{1}{(1 - \Theta/R)\varepsilon_b}$ is the industry-wide markdown in cattle prices from cattle's marginal value and e_b is the error term for the Bertrand margin equation respectively. However, the parameters in the industry-wide markdown cannot be estimated because of limitation of firm level data. Consequently, we estimate the whole part of the industry-wide markdown, $M = \frac{1}{(1 - \Theta/R)\varepsilon_b}$, as follow:

(3.13) $$P - W = M \cdot W + \sum_k \sum_j \alpha_{kj} (v_k v_j)^{1/2} + e_b .$$

To estimate the margin equations (3.13), simultaneous equations are needed such as three non-farm input demand equations. Non-farm input demands are obtained by applying Shephard's lemma on the industry level processing cost function represented by equation (3.10) as:

(3.14) $$\frac{\partial C(Q, \mathbf{v})}{\partial v_j} = X_j = Q \sum_k \alpha_{kj} \left(\frac{v_k}{v_j} \right)^{1/2} + \beta_j ,$$

which can be re-arranged as:

(3.15) $$\frac{X_j}{Q} = \sum_k \alpha_{kj} \left(\frac{v_k}{v_j} \right)^{1/2} + \frac{\beta_j}{Q} + e_j ,$$

where X_j is the industry level derived non-farm input demand for labor, capital, and material, X_j / Q is the inverse of productivity for each non-farm input, and e_j is the error term for the non-farm input demand equation respectively.

Finally, to analyze the effect of concentration, cattle cycle, and seasonality on the cattle price, we make the markdown as a function of these variables. This specification also allows the dynamic estimation of the market conduct over time. The industry-wide markdown M is specified as:

(3.16) $$M = \gamma_0 + \gamma_1 H + \gamma_2 C + \gamma_3 D_1 + \gamma_4 D_2 + \gamma_5 D_3,$$

where H is the Herfindahl-Hirschman Index, C is the cattle cycle, and D_i with $i = 1, 2, 3$ are seasonal dummy variables, and γ 's are parameters. In order to generate cattle cycle variability, the following yearly cattle supply equation is estimated:

(3.17) $$Q = \delta_0 + \delta_1 time + \varepsilon_q,$$

and the cattle cycle variable, $C = Q - \hat{Q}$, is calculated for each year. If equation (3.16) substitutes into equation (3.13), then dynamic equation can be written as:

(3.18) $$P - W = (\gamma_0 + \gamma_1 H + \gamma_2 C + \gamma_3 D_1 + \gamma_4 D_2 + \gamma_5 D_3) \cdot W + \sum_k \sum_j \alpha_{kj} (v_k v_j)^{1/2} + e_d .$$

We utilize two systems: the static model and the dynamic model for three regions: National, Nebraska, and Texas. Equations (3.13) and (3.15) constitute a system of four equations for the static model and equations (3.18) and (3.15) constitute a system of four equations for the dynamic model. We use the generalized method of moment (GMM) which employs instrumental variable estimators since the system equations have endogeneity problems. GMM also provides a consistent estimator when heteroskedasticity and autocorrelation are present (Breusch 1978; Godfrey 1978). The eighteen instrumental variables included in the equation are Herfindahl-Hirschman Index (HHI) for the steer and heifer slaughter, 5 market steer weighted price, Nebraska steer and heifer weighted price, Texas steer and heifer weighted price, labor price, capital price, material price, cattle on feed, cattle placement, cattle on marketing, disappearance, cycle, seasonal dummy variables, time, and squared time. The industry-wide markdown rates as market power indices and markdowns in cattle prices from cattle's marginal value for each year are also estimated through GMM using the MODEL Procedure in SAS 9.2.

The first null hypothesis is that oligopsony market power in the U.S. cattle procurement market equal zero. Rejecting it suggests that packers exert oligopsony market power in the U.S. cattle procurement market. The second null hypothesis is that the concentration, the cattle cycle, and the seasonality have no effect on the oligopsony market power. Rejecting it suggests that the concentration, the cattle cycle, and the seasonality might be used as a way to price under the marginal cost for cattle production.

Data

In this paper, we use monthly data series for the U.S. cattle procurement market ranging from 1980 to 2009. As National, Nebraska, and Texas cattle supplies, the steer and heifer slaughter total live weights for National level, for Nebraska region, and Texas region are from Livestock Slaughter Annual Summary of United States Department of Agriculture (USDA). The wholesale price and the 5 market steer weighted price data are from the beef value and price spread monthly data sets from the USDA Economic Research Service (ERS). The wholesale price is modified by including by-product value and by dividing with 2.4 as conversion factor to a unit of live cattle (USDA). The steer and heifer weighted prices data for Nebraska and Texas are compiled from USDA Agricultural Marketing Service (AMS) data. The producer price index for farm products slaughter steer and heifer is from Bureau Labor Statistics (BLS). The price index and the productivity index of labor, capital, and material for U.S. food and other industries are obtained from the Major Sector Multifactor Productivity Index Database of BLS. The cattle on feed, the cattle placement, the cattle on marketing, and disappearance data are from the USDA National Agricultural Statistics Service and Red Meats Yearbook of USDA. The Herfindahl-Hirschman Index for the U.S. beef processing industry is the steer and heifer slaughter concentration index compiled from several annual reports from the Packers and Stockyards Statistical Report (1996-2009). The definitions and descriptive statistics of these variables are presented in table III-1.

Empirical Results

The estimation results of the static model and the dynamic model for the National level, Nebraska region, and Texas region by GMM are reported in table III-2 and III-3. All of the 10 parameter estimates in the static model and most parameter estimates in the dynamic model for National, Nebraska, and Texas are statistically significant at the 5% significance level.

With these estimation results and with mean values of cattle prices and input prices, the market power parameters such as market power (industry-wide markdown rate), markdown, and marginal cost are calculated and summarized in table III-4. As the key parameter, the market power estimates in the static model are 0.0366, 0.0199, and 0.0138 for National, Nebraska, and Texas respectively while 0.0629, 0.0401, and 0.0377 in the dynamic model. The market power of National is the biggest compared to the two regions and the market power of Nebraska is greater than the market power of Texas. The market power from the dynamic model shows the same results with the static model, but their value is almost twice that of the static models'. The values of 0.0366, 0.0199, and 0.0138 for market power in the static model mean that there are about 3.66 percent, 1.99 percent, and 1.38 percent of markdowns for the cattle price respectively.

For the markdowns and the marginal costs, in the static model, the markdowns are 2.6537, 1.4368, and 1.0039 and the marginal costs are 6.7237, 8.1916, and 8.0956 for National, Nebraska, and Texas respectively and they are all significant at the 5% significance level. In the dynamic model, the markdowns are 4.5645, 2.8905, and 2.7486 and the marginal costs are 5.3866, 6.9359, and 6.5899 for National, Nebraska, and Texas respectively and they are also all significant at the 5% significance level. The markdown value of 2.6537 and marginal cost of 6.7237 for National in the static model mean that the average markdown for the cattle price is $ 2.65/cwt and the marginal cost of cattle slaughter is $ 6.72/cwt, respectively. These results of market power and markdown for Nebraska and Texas in the static model are similar to the results of Schroeter (1988) and Stiegert, Azzam, and Brorsen (1993) while the results for National and dynamic model are slightly bigger than their results.

The dynamic model shows the effect of concentration, cattle cycle, and seasonality. The parameters of concentration, cattle cycle, and three seasonal variables for National are -0.2491, 0.0082, -0.0122, 0.0169, and 0.0085 respectively. They are all significant at the 5% significance level. Nebraska and Texas also show similar estimation results. These results signify that concentration has a negative impact on the cattle price markdown. That is, the markdown in cattle price is decreased by increasing the concentration. This result coincides with a majority of results from similar studies (Azzam 1997; Stiegert, Azzam, and Brorsen 1993). The parameters of cattle cycle and seasonality for May-July and Aug-Oct are positive while the parameter of seasonality for Feb-Apr is negative. This result means that when the cattle supply is greater than the normal trends (or expected supply), packers exercise more market power in the cattle procurement market and vice versa. This result supports the view of SCP that when the cattle supply is inflated the packers tacitly collude to drop the cattle price. When the cattle supply is short the packers bid aggressively to get some amount of cattle in the cash market.

The dynamic model allows market power to change over time, so we calculate the market powers for each year. Figure III-4 shows the changes of the market power and cattle supply. The cattle supply fluctuates with an increasing trend while market power fluctuates with a decreasing trend. This decreasing trend of market power is incompatible with the traditional opinion that an increase of concentration will increase market power. However, the market power for National, Nebraska, and Texas have fluctuated along with the cattle cycle over the given time period. Therefore, we can conclude that the cattle cycle causes the oligopsony market power in the cattle procurement market and that the market power has been fluctuating and declining over time. This finding also coincides with the previous studies (Stiegert, Azzam, and Brorsen 1993; Crespi, Xia, and Jones 2010).

In summary, the first null hypothesis that oligopsony market powers in the U.S. cattle procurement market equal zero is rejected in all regions and both static and dynamic model. Therefore, we can conclude that packers exert an oligopsony market power over the U.S. cattle procurement market. The second null hypotheses that the concentration, the cattle cycle, and the seasonality have no effect on the oligopsony market power are all rejected. That means the packers use the cattle supply and the seasonality to increase their margins by pricing cattle under the marginal cost of cattle production. However, the concentration has a negative effect on the oligopsony market power. That is, the markdown decreases by increasing the concentration for the sample period. This result may support the hypothesis that cost efficiency dominates the effect of market power by increasing the concentration.

Conclusions

There are many controversial issues about market power in the U.S. cattle procurement market. Many believe that the major beef processing companies attempt to merge and acquire the other companies as a viable strategy to increase their market powers. However, some studies indicate that such consolidation amongst packers leads to the increase of their efficiency in beef processing cost, rather than increasing the market power. Therefore, this study looks into the beef packing industry from the perspective that the market power may not be from the concentration, but from the characteristics of cattle production such as cattle cycle and seasonality. If the market power is caused by cattle supply, then the packers may compete with price instead of quantity. That is, following the SCP theory, when the cattle supply is short the packers might bid aggressively for procuring the cattle (low markdown) and when the cattle supply is enough the packers will bid less aggressively (high markdown).

From this view point, we use the Bertrand model that assumes price competition in the market and we compare it to the Cournot model. In addition, the dynamic model with the time varying model is used to look into the dynamic change of market conducts which is caused by the concentration, the cattle cycle, and the seasonality for the U.S. cattle procurement market. Three regions: National, Nebraska, and Texas, are estimated with the monthly data from 1980 to 2007.

The empirical results show that there exists oligopsony market power in the U.S. cattle procurement market. The oligopsony market power is influenced by the cattle cycle and seasonality. That is, the packers may tacitly collude during the excessive cattle supply period, while biding to price more aggressively during the short cattle supply period. The variation of market power equivalently changes with the cattle cycle. However, concentration has a negative effect on market power in cattle procurement market. These results suggest that it is more important to make cattle supply stable and to continue monitoring the cattle procurement market to assure a competitive performance. Nevertheless, this research is limited in estimating the Bertrand model derived from this study because the parameters to be estimated require firm level data. Therefore, additional research needs to develop a more suitable model to continue this study.

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Notes

1. Average processing cost (APC) pricing is that packers establish a cattle bid price by subtracting the average processing cost from the price received for carcasses or boxed beef while the structure-conduct-performance (SCP) paradigm theory suggests that the markdown will respond to supply changes, but in a direction opposite to that of APC pricing. That is, as anticipated supply declines, packers bid more aggressive while anticipated supply is abundant, bidding becomes less aggressively and the markdown increases (Stiegert, Azzam, and Brorsen 1993).
2. The Bertrand model rests on the following assumptions: 1) There are at least two firms producing homogeneous (undifferentiated) products; 2) Firms do not cooperate; 3) Firms compete by setting prices simultaneously; 4) Consumers buy everything from a firm with a lower price. If all firms charge the same price, consumers randomly select among them (Bertrand 1883). The fourth assumption represents that the own price elasticity is infinite.
3. Koontz, Garcia, and Hudson (1993) interpret the value of $\Theta = 0$ means packers display non-cooperative pricing and the value of $\Theta > 0$ means packers have cooperative pricing in the cattle procurement market.

Table III-1. Descriptive Statistics of Variables Used in the Empirical Estimation (1980.1-2009.12, N=360)

Variable	Symbol	Mean	S. D.	Minimum	Maximum
National margin (cattle price based) ($/cwt)	$P-W$	10.82	2.87	4.64	21.04
Nebraska margin (cattle price based) ($/cwt)	$P-W$	11.12	2.83	4.81	22.05
Texas margin (cattle price based) ($/cwt)	$P-W$	10.39	3.09	4.63	20.38
Wholesale price of boxed beef ($/cwt)	P	201.10	29.65	146.00	292.99
National cattle price (5 market steer price) ($/cwt)	W	72.47	10.30	52.33	100.67
Nebraska cattle price (steer and heifer weighted price) ($/cwt)	W	72.16	10.27	52.70	102.63
Texas cattle price (steer and heifer weighted price) ($/cwt)	W	72.88	10.23	53.80	99.81
Herfindahl Hirschman index for steer and heifer slaughter	H	0.1606	0.0464	0.0561	0.2096
National steer and heifer slaughter weight (bil./lbs)	Q	2.6673	0.2852	2.0420	3.3290
Nebraska steer and heifer slaughter weight (bil./lbs)	Q	1.3669	0.2081	0.9169	1.8218
National steer and heifer slaughter weight (bil./lbs)	Q	0.4958	0.0625	0.3683	0.6640
Labor productivity (2000=100)	Q/X_l	97.04	8.13	83.57	112.85
Price of labor (2000=100)	v_l	88.88	27.14	44.26	138.92
Capital productivity (2000=100)	Q/X_c	102.25	1.73	99.58	105.62
Price of capital (2000=100)	v_c	78.37	20.53	45.92	111.85
Material productivity (2000=100)	Q/X_m	90.56	7.87	78.18	102.57
Price of material (2000=100)	v_m	100.83	21.26	70.50	159.97
PPI for farm products slaughter steers and heifers (2000=100)	PPI	104.63	14.32	73.28	157.47
Cycle (bil./lbs)	C	0.0036	1.4399	-2.4688	2.1768

Table III-2. GMM Estimates of the Parameters for the Static Model for the National, Nebraska, and Texas regions cattle procurement market

Parameter	Natioanl	Nebraska	Texas
M	0.0366 (0.0035)	0.0199 (0.0030)	0.0138 (0.0030)
α_{ll}	2.5482 (0.0646)	2.8537 (0.0030)	2.3866 (0.0563)
α_{cc}	0.8399 (0.0196)	0.5890 (0.0122)	0.4369 (0.0083)
α_{mm}	3.2068 (0.0881)	3.1615 (0.0783)	2.7948 (0.0716)
α_{lc}	0.1974 (0.0090)	0.1036 (0.0096)	0.2540 (0.0093)
α_{cm}	-0.8431 (0.0247)	-0.5181 (0.0154)	-0.5190 (0.0144)
α_{ml}	-2.5985 (0.0681)	-2.8287 (0.0673)	-2.4834 (0.0610)
β_l	0.2767 (0.0113)	0.1997 (0.0071)	0.0420 (0.0023)
β_c	-0.1801 (0.0094)	-0.1188 (0.0045)	-0.0477 (0.0014)
β_m	-0.1562 (0.1031)	-0.1279 (0.0069)	-0.0174 (0.0023)

Notes: All parameters are significant at the 5% significance level.
Parentheses are approximate standard errors.

Table III-3. GMM Estimates of the Parameters for the Dynamic Model for the National, Nebraska, and Texas regions cattle procurement market

Parameter	National	Nebraska	Texas
γ_0	0.0996 (0.0048)**	0.0556 (0.0068)**	0.0467 (0.0057)**
γ_1	-0.2491 (0.0193)**	-0.1017 (0.0266)**	-0.0923 (0.0231)**
γ_2	0.0082 (0.0005)**	0.0078 (0.0005)**	0.0078 (0.0005)**
γ_3	-0.0122 (0.0021)**	-0.0156 (0.0023)**	-0.0096 (0.0023)*
γ_4	0.0169 (0.0024)**	0.0138 (0.0026)**	0.0216 (0.0024)**
γ_5	0.0085 (0.0026)**	0.0049 (0.0027)*	0.0113 (0.0026)**
α_{ll}	2.2445 (0.0899)**	3.4504 (0.1371)**	2.8893 (0.1079)**
α_{cc}	1.2642 (0.0520)**	1.2656 (0.0505)**	1.1123 (0.0396)**
α_{mm}	1.5938 (0.0736)**	2.1705 (0.0993)**	1.7552 (0.0786)**
α_{lc}	-0.7592 (0.0311)**	-1.1053 (0.0434)**	-0.9295 (0.0331)**
α_{cm}	-0.3474 (0.0182)**	-0.0063 (0.0116)	-0.0282 (0.0069)**
α_{ml}	-1.4017 (0.0595)**	-2.2825 (0.0971)**	-0.8708 (0.0765)**
β_l	0.0302 (0.0191)	0.1341 (0.0158)**	0.0174 (0.0044)**
β_c	-0.1331 (0.0146)**	-0.1042 (0.0083)**	-0.0415 (0.0026)**
β_m	0.0410 (0.0147)**	-0.0690 (0.0116)**	0.0052 (0.0036)

Notes: * significant at the 10% significance level.
** significant at the 5% significance level.
Parentheses are approximate standard errors.

Table III-4. Oligopsony Market Power, Markdown, and Marginal Cost for the U.S. Cattle Procurement Market

Market Power	Static Model			Dynamic Model		
	National	Nebraska	Texas	National	Nebraska	Texas
Market Power	0.0366	0.0199	0.0138	0.0629	0.0401	0.0377
(%)	(0.0035)	(0.0030)	(0.0030)	(0.0030)	(0.0036)	(0.0035)
Markdown	2.6537	1.4368	1.0039	4.5645	2.8905	2.7486
($/cwt)	(0.2525)	(0.2188)	(0.2159)	(0.2200)	(0.2578)	(0.2575)
Marginal Cost	6.7237	8.1916	8.0956	5.3866	6.9359	6.5899
($/cwt)	(0.1965)	(0.1700)	(0.1682)	(0.1763)	(0.1954)	(0.2091)

Notes: Parentheses are approximate standard errors.
All estimates are statistical significant at the 5% significance level.

Figure III-1. The Concentration (HHI for Steer and Heifer) Change for U.S. Cattle Procurement Market from 1980 to 2009

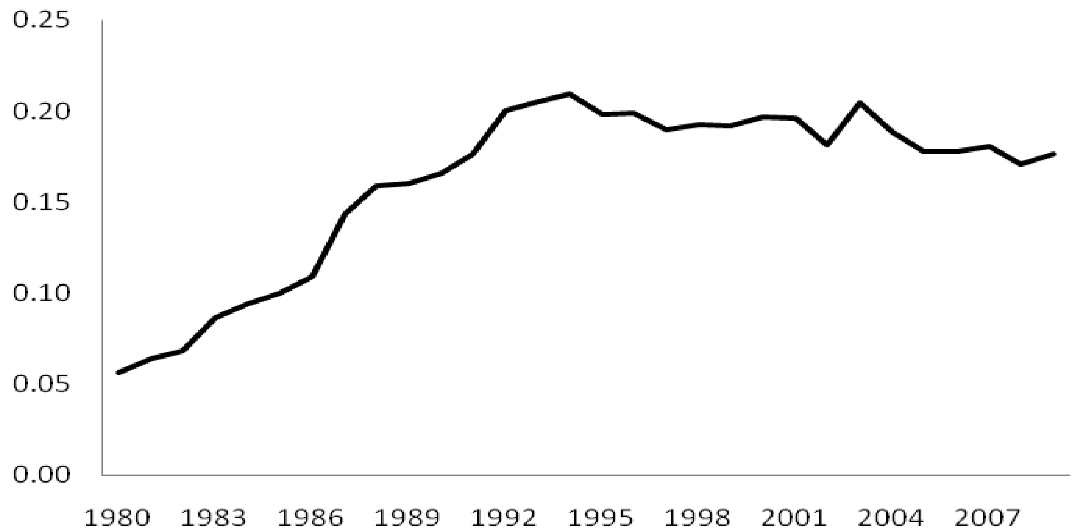


Figure III-2. The Cattle Supply for the U.S. Cattle Procurement Market from 1980 to 2009

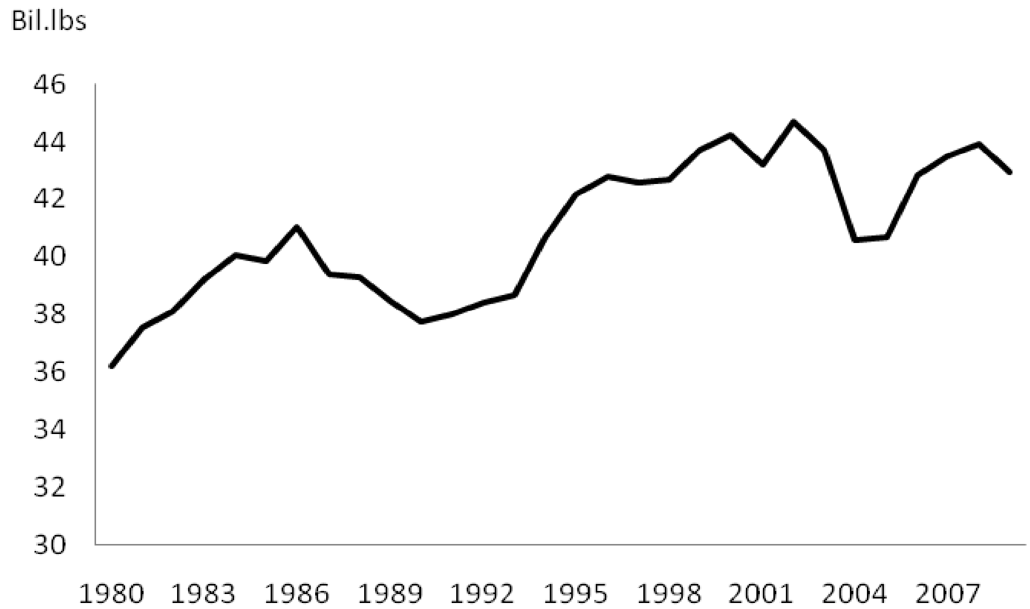


Figure III-3. The Average Monthly Changes of Slaughtered Cattle for the U.S. Cattle Procurement Market from 1980 to 2009

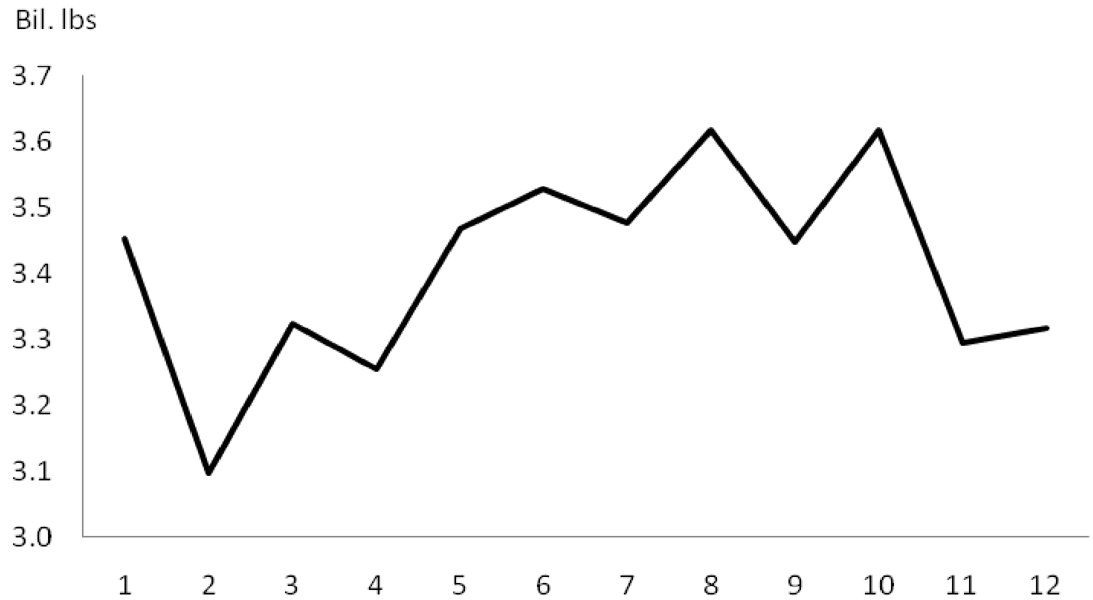
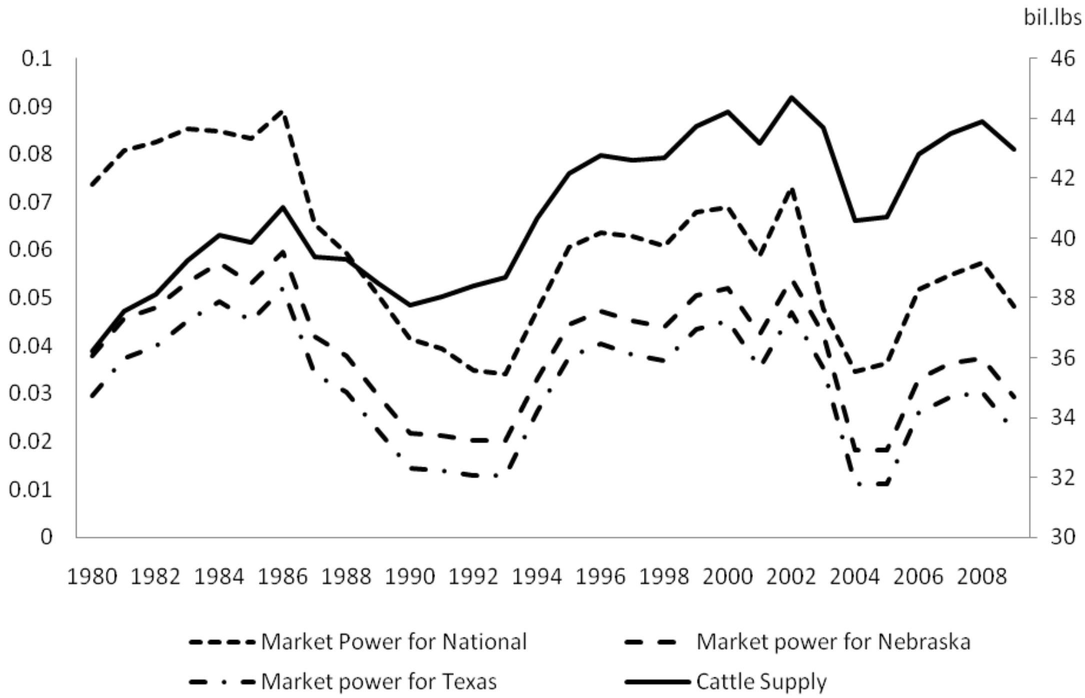


Figure III-4. The Changes of Market Power and Cattle Supply for the U.S. Cattle Procurement Market from 1980 to 2009



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This study consists of three essays. The first essay tests the causality between captive supply and cash market price in the U.S. cattle procurement market. Three causality tests, the Granger test, the Sims test, and the Modified Wald test, were conducted for four relationships: cash market price-total captive supply, cash market price-marketing agreement, cash market price-forward contract, and cash market price-packer fed cattle. All three tests indicate that cash market price is caused by total captive supply and marketing agreement. The Modified Wald test shows the bidirectional causality between cash market price and forward contract. Also, the Modified Wald test finds no causal relationship between cash market price and packer fed cattle. Overall test results indicate that captive supply causes cash market price, and the results favor the price dependent model over the quantity dependent model.

The second essay measures the impacts of concentration and captive supply on oligopoly and oligopsony market power and cost efficiency in the U.S. beef packing industry using both static and dynamic empirical industrial organization models. Two separate sources of oligopsony power are considered: the cash cattle procurement market and the captive supply market. The results show the presence of market powers in both beef retail and cattle procurement markets. The oligopsony market power is greater but more unstable than oligopoly market power throughout the entire sample period. Concentration and captive supply play a role in increasing market power. The cost efficiency effects caused by increasing concentration and captive supply outweigh the market power effects.

The third essay uses the new empirical industrial organization approach with the Bertrand model to measure the oligopsony market power in the U.S. cattle procurement market. It tests whether the market power is caused by concentration, cattle cycle, and seasonality. The results show that the oligopsony market power exists in the U.S. cattle procurement market. The cattle cycle and seasonality affect the oligopsony market power and the cattle cycle causes the change in market power. However, concentration has a negative effect on the oligopsony market power.

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