Changing Impacts of Beef Demand on Cattle Producers

Melissa McKendree, PhD Candidate, Kansas State University, mgsm@ksu.edu

Glynn T. Tonsor, Professor, Kansas State University

Ted C. Schroeder, Professor, Kansas State University

Nathan P. Hendricks, Associate Professor, Kansas State University

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Abstract

Economists have long recognized changes in consumer demand directly impact stakeholders throughout corresponding supply chains. However, empirical applications quantifying how demand signals are transmitted through vertically connected industries are limited. One study which provided empirical linkages between changes in retail level U.S. beef demand and economic welfare of beef producers was provided by Marsh (2003). However, given the changing landscape of the beef industry, changing consumer preferences, and globalization this paper is outdated. Our analysis aims to provide an improved quantification of how changes in retail and export beef demand are transmitted to different members of the beef industry.

Keywords: Beef, Cattle, Demand, Economic Impacts, Exports, Producer Welfare, Transmission Elasticities

Over the past 40 years, consumer food preferences and perceptions of agriculture and meat production have been changing. U.S. consumers are increasingly interested in knowing both the physical attributes (e.g., nutrition, health, and safety) of their food as well as how it is produced (e.g., sustainable, animal welfare, and natural). Similarly, production segments of the U.S. food supply chain are keenly interested in economic impacts of these changes. The beef industry is no exception, experiencing dramatic changes in consumer demand over the past several decades (Tonsor, 2014). The beef industry has invested considerable resources to provide consumers with beef products possessing attributes they prefer as well as in product development and promotion (Kaiser, 2014; Tonsor, Schroeder, and Mintert, 2015). While existing research provides extensive insights into meat demand (see Bryant and Davis, 2008 and Gallett, 2010 for reviews), the literature on how changes in consumer demand impact producers is comparably limited. As such, the beef industry is intensively interested in knowing how changing primary beef demand is shared among consumers, retailers, packers/processors, feedlots, cow-calf producers, and other members of the production and marketing channel.

Increased interest in food production, together with food industry positioning and product promotion, influence consumer demand. Conceptually as consumer demand varies, the impacts are passed down through the marketing chain to producers through derived demand. Despite this well-known concept, empirical efforts to quantify these effects are limited and dated. The objective of this paper is to estimate transmission of retail level and export demand signals through the U.S. beef industry to cattle producers.

How demand changes are transmitted to other levels of vertical supply chains is important to quantify. These estimates are utilized in policy analysis and estimating impacts of new technologies (e.g., Balagtas and Kim, 2007; Pendell et al., 2010; Weaber and Lusk, 2010; Okrent and Alston, 2012). Similarly, price-transmission estimates are essential when quantifying distributional impacts of events in industries comprised of multiple segments (Kinnucan, Hsia, and Jackson, 1997; Wohlgenant, 1993) such as the U.S. beef industry. A recent example was the effort to initiate a second checkoff program in the U.S. beef-cattle industry (USDA, 2014). This in large part has arisen following a long-standing debate about how cattle producers benefit from investments in enhancing consumer beef demand. The need for this study was highlighted by

Wohlgenant (2006): "For the most part, research has not focused on one very important aspect of estimating the rates of return to advertising – the retail-to-farm price transmission." (p. 2).

During the 1980s and 1990s, U.S. consumer preferences rapidly changed and consumer demand for beef declined (Genho, 1998; Purcell, 1989; Schroeder, 2000; Marsh, 2003; Schroeder, Marsh, and Mintert, 2000). To better understand how to respond to this precipitous decline, the beef industry needed more information about how beef packers, cattle feedlots, and cow-calf producers were impacted. Marsh (2003) is the most definitive quantification of how retail beef demand impacted farm level derived demand. Up until his study, the econometric linking of shifts in retail beef and farm level demands, supplies, and revenues was overlooked (Marsh, 2003). The implications of retail demand shifts for those in the beef marketing channel are perhaps even more important today. However, no study has continued Marsh's work which is now more than a decade old in an industry that has experienced massive changes in demand as well as supply.

One notable change in the U.S. beef industry is the increased role of exports. From the early 1980s to 2013 beef export volume grew ten-fold from around 1% to about 10% of production (LMIC, 2014). The heightened importance of exports in the beef market were especially evident in late 2003 and 2004 when foreign markets halted imports of U.S. beef due to discovery of bovine spongiform encephalopathy (BSE) in the U.S. beef herd. Marsh, Brester, and Smith (2008) concluded "the demand for U.S. beef was affected to a much greater degree by the reactions of foreign governments to the BSE announcements than by the reactions of U.S. households" (p. 136). The future role of beef exports is expected to increase reflecting global economic growth and expanding meat protein demand. The Economic Research Service projects that over 13% of domestic production will be exported by 2023 (Westcott and Trostle, 2014).

Model Development and Data

Our conceptual model uses the Marsh (2003) model as the foundation, however it has been changed and expanded in multiple ways to reflect the evolving structure of the beef industry.

Demand Indices

A key component in Marsh (2003) is the integration of a price based beef demand index (1970=100) into the econometric system to represent annual shifts in U.S. retail domestic beef demand. However, Brester, Bekkerman and Tonsor (2016) found quantity based indices to produce more accurate changes in demand than the price based indices. Following Brester, Bekkerman and Tonsor (2016) we construct a quantity based index as:

$$I_{quanitity,z} = \left(\frac{Q_{t,z}}{Q_{t,z}^e}\right) * 100 = \frac{Q_{t,z}}{Q_{0,z} + \left\{Q_{0,z} * \left[\left(\frac{P_{t,z} - P_{0,z}}{P_{0,z}}\right) * \left(\frac{\%\Delta Q_z}{\%\Delta P_z}\right)\right]\right\}} * 100$$

Q_t is the actual per capita quantity of beef consumed in year t, quarter z. $Q_{t,z}^e$ is the expected per capita consumption that would have occurred if there had been no change in demand in year t, quarter z. $Q_{0,z}$ is the base year/quarter quantity. $P_{t,z}$ is the price in year t, quarter z, while $P_{0,z}$ is the base year/quarter price. $\frac{\%\Delta Q_z}{\%\Delta P_z}$ is the own-price elasticity of demand.

For the U.S. retail beef demand index, $P_{t,z}$ is the choice retail beef price in $/lb, deflated by the consumer price index. $Q_{t,z}$ is the retail per capita consumption in lbs. The base year is 1996. The demand elasticity is assumed to be -0.67 (Marsh, 2003; Genho,1998). The quarterly U.S. retail beef demand indices for 1996Q1 to 2016Q3 are shown in figure 1.

Additionally, we create an index for U.S. beef exports by the rest of the world. $Q_{t,z}$ is the rest of the world per capita consumption of U.S. total beef and veal, and variety meat exports, in lbs. $P_{t,z}$ is the nominal beef export price in $/lb[1]. The assumed elasticity of demand is -0.42 (Zhao, Wahl, and Marsh, 2006). The base year is 1996. The quarterly U.S. beef export demand indices for 1996Q1 to 2016Q3 are shown in figure 2. Two central questions of interest are how changes in U.S. retail and export beef demand have impacted farm level cattle prices and quantities.

Conceptual Model

The U.S. beef industry is comprised of multiple segments. In a simplistic version the cow-calf sector supplies feeder calves to feedlots. Animals are fed to harvest weight at the feedlot and then sold to the packer. After harvest, the packer then distributes the wholesale beef through

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[1] Created using $\frac{(Value\ of\ total\ beef\ and\ veal + Value\ of\ variety\ meat\ beef)}{Pounds\ of\ total\ beef\ and\ veal + pounds\ of\ variety\ meats\ beef}$

multiple outlets including traditional domestic retail outlets and beef for exports. Thus, derived supply and demand theory can be applied to the U.S. beef industry. Whenever exogenous factors increase (decrease) primary demand, derived demands are also expected to increase (decrease) (Tomek and Robinson, 2003). Figure 3 illustrates changes to derived demand and supply curves due to an exogenous increase in U.S. retail level demand. An exogenous increase in retail beef demand induces retailers to increase demand for wholesale beef from packers, resulting in an upward shift from D_{Fed} to D_{Fed}'. This increased demand for beef at the Fed cattle level, causes feedlot operators to demand more cattle from cow-calf and stocker operations (shifting D_{Feeder} upward to D_{Feeder}'). Upward shifts in demand will result in higher prices and quantities at the Fed and feeder levels. The exact increase in prices is an empirical question of central interest in this study.

We use the Marsh (2003) simultaneous equations system of inverse demand and primary supply equations for the U.S. fed and feeder cattle sectors as the building block for our conceptual model of the U.S. beef industry. We update this system in multiple ways detailed below. The conceptual model of live and feeder cattle supply and demand is:

Live (fed) cattle equations:

$$P_t^{L,D} = \Psi_1\big(Q_t^{L,D}, RDI_t, EI_t, M_t, time, Q_t^2, Q_t^3, Q_t^4, \mu_t^1\big) \qquad \text{(inverse live cattle} \qquad (1)$$

demand)

$$Q_t^{L,S} = \Psi_2\big(E_{t-2}[P_t^{L,S}], P_{t-2}^F, P_{t-i}^C, I_{t-2}, time_t, Q_{t-1}^L, Q_t^2, Q_t^3, Q_t^4, \mu_t^2\big) \text{ (live cattle supply)} \qquad (2)$$

$$Q_t^{L,D} = Q_t^{L,S} = Q_t^L; \; P_t^{L,D} = P_t^{L,S} = P_t^L \qquad \text{(market clearing)} \qquad (3)$$

Feeder cattle equations:

$$P_t^{F,D} = \Psi_3\big(Q_t^{F,D}, E_t[P_{t+2}^{L,D}], E_t[P_{t+j}^C], E_t[I_t], time_t, Q_t^2, Q_t^3, Q_t^4, \mu_t^3\big) \text{ (inverse feeder cattle demand)} \qquad (4)$$

$$Q_t^{F,S} = \Psi_4\big(P_t^{F,S}, E_{t-8}[P_t^{F,S}], P_{t-4}^W, P_t^H, P_{t-8}^H, time_t, Q_{t-1}^{F,S}, Q_t^2, Q_t^3, Q_t^4, \mu_t^4\big) \qquad \text{(feeder supply)} \qquad (5)$$

$$Q_t^{F,D} = Q_t^{F,S} = Q_t^F; \; P_t^{F,D} = P_t^{F,S} = P_t^F \qquad \text{(market clearing)} \qquad (6)$$

Other:

$$RDI_t = \Psi_5(PGDP_t^{US}, Q_t^2, Q_t^3, Q_t^4, \mu_t^5) \qquad \text{(retail demand index)} \qquad (7)$$

$$EI_t = \Psi_6\big(PGDP_t^{World}, EX_t, Q_t^2, Q_t^3, Q_t^4, \mu_t^6\big) \qquad \text{(export demand index)} \qquad (8)$$

where $i = 1,2$ and $j = 0,1$. A list of complete variables and descriptions can be found in table 1 (μ_1 to μ_6 are error terms). The quarterly lag structure was determined based on biological considerations and time it takes for a calf to be born, fed and harvested.

Equation (1) is derived inverse live (or fed) cattle demand where live cattle price at time t ($P_t^{L,D}$) is a function of the quantity demanded of fed cattle by beef packers ($Q_t^{L,D}$), retail beef demand quantified by the beef demand index (RDI_t), export beef demand quantified by the export index (EI_t), food marketing costs (M_t) and seasonality (Q_t^2, Q_t^3, Q_t^4). Including the beef and export demand indices allows for shifts in the primary demand to impact beef packer derived demand. A time trend is included to account for technological changes.

Fed cattle supply, equation 2, is a function of the expected output price ($E_{t-2}[P_t^{L,S}]$) at time of placement. We assume a six month (two quarter) feeding window. The input prices are feeder cattle price (P_{t-2}^F) at placement and corn price (P_{t-i}^C). Corn can all be purchased at placement (P_{t-2}^C) or midway through the feeding period (P_{t-1}^C). Interest rates (I_{t-2}) at placement account for the opportunity cost of money. A lagged dependent variable (Q_{t-1}^L) and seasonality (Q_t^2, Q_t^3, Q_t^4) are also included. Time is included to account for technological changes in cattle feeding over time in the absence of a better technology variable. Equation (3) is the market clearing condition.

Equations (4) through (6) are feeder cattle inverse demand, supply and market clearing equations. In equation (4), feeder cattle price ($P_t^{F,D}$) is a function of feeder cattle quantity demanded by feedlots ($Q_t^{F,D}$), the expected $t + 2$ fed cattle price ($E_t[P_{t+2}^{L,D}]$) at time t (expected price the animal will sell for at the end of the feeding period), the expected corn price at time t ($E_t[P_{t+j}^C]$), expected interest rate at time t ($E_t[I_t]$), time used as a proxy for technology in cattle finishing, and seasonality (Q_t^2, Q_t^3, Q_t^4). The retail and export demand implicitly enter this equation through $E_t[P_{t+2}^{L,D}]$.

Equation (5) presents quantity of feeder cattle supplied ($Q_t^{F,S}$) as a function of feeder cattle price at time t ($P_t^{F,S}$), the expected feeder cattle price ($E_{t-8}[P_t^{F,S}]$) at time $t - 8$, cull cow price (P_{t-4}^W), hay price (P_t^H and P_{t-8}^H), time as a proxy for technology, lagged dependent variable ($Q_{t-1}^{F,S}$), and seasonality (Q_t^2, Q_t^3, Q_t^4). $E_{t-8}[P_t^{F,S}]$ represents the opportunity cost of heifer

retention. P_{t-4}^W represents the opportunity cost of holding a cow versus culling. P_t^H is used to proxy pasture conditions and the decision to sell the animal now, or wait and sell next period. P_{t-8}^H can be used to judge pasture conditions and a potential indication of herd size (poor pasture conditions generally decrease the herd size).

Equations (7) and (8) are used to account for the potential endogeneity of retail and export beef demand. Retail beef demand is a function of per capita U.S. GDP ($PGDP_t^{US}$) and seasonality (Q_t^2, Q_t^3, Q_t^4). Export beef demand is a function of the rest of the world per capita GDP ($PGDP_t^{World}$), exchange rate (EX_t), and seasonality (Q_t^2, Q_t^3, Q_t^4). Other identification options are also being explored.

Data

Quarterly data for 1996 quarter 1 to 2016 quarter 3 were collected from multiple sources. Descriptive statistics of variables for this analysis can be found in table 2. Note, all prices (unless otherwise noted) and the marketing cost index were deflated by the Consumer Price Index (CPI where 1982-84=100). Specific details regarding data sources and data manipulations are provided in the Appendix A.

Econometric Model

If naïve expectation are assumed, the full six-equation model (Equations (9) through (14)) below can be estimated using iterative three-stage least squares in log-log form:

Live (fed) cattle equations:

$$lnP_t^L = \alpha_1 + \alpha_2 lnQ_t^L + \alpha_3 lnRDI_t + \alpha_4 lnEI_t + \alpha_5 lnM_t + \alpha_6 lntime_t + \alpha_7 Q_t^2 +$$
$$\alpha_8 Q_t^3 + \alpha_9 Q_t^4 + \mu_t^1 \text{ (inverse live cattle demand)} \tag{9}$$

$$lnQ_t^L = \beta_1 + \beta_2 lnP_{t-2}^L + \beta_3 P_{t-2}^F + \beta_4 lnP_{t-i}^C + \beta_5 I_{t-2} + \beta_6 lntime_t + \beta_7 lnQ_{t-1}^L +$$
$$\beta_8 Q_t^2 + \beta_9 Q_t^3 + \beta_{10} Q_t^4 + \mu_t^2 \text{ (live cattle supply)} \tag{10}$$

Feeder cattle equations:

$$ln P_t^F = \delta_1 + \delta_2 ln Q_t^F + \delta_3 ln P_t^L + \delta_4 ln P_{t+j}^C + \delta_5 ln I_t + \delta_6 ln time_t + \delta_7 Q_t^2 +$$
$$\delta_8 Q_t^3 + \delta_9 Q_t^4 + \mu_t^3 \text{ (inverse feeder cattle demand)} \tag{11}$$

$$\ln Q_t^F = \gamma_1 + \gamma_2 \ln P_t^F + \gamma_3 \ln P_{t-8}^F + \gamma_4 \ln P_{t-4}^W + \gamma_5 \ln P_t^H + \gamma_6 \ln P_{t-8}^H +$$
$$\gamma_7 \ln time + \gamma_8 \ln Q_{t-1}^F + \gamma_9 Q_t^2 + \gamma_{10} Q_t^3 + \gamma_{11} Q_t^4 + \mu_t^4 \text{ (feeder supply)} \tag{12}$$

Other equations:

$$\ln RDI_t = \rho_1 + \rho_2 \ln PGDP_t^{US} + \rho_3 Q_t^2 + \rho_4 Q_t^3 + \rho_5 Q_t^4 + \mu_t^5 \tag{13}$$

$$\ln EI_t = \omega_1 + \omega_2 \ln PGDP_t^{World} + \omega_3 EX_t + \omega_4 Q_t^2 + \omega_5 Q_t^3 + \omega_6 Q_t^4 + \mu_t^6 \tag{14}$$

Results

Results will be presented at the conference.

Conclusion

Although conceptually agreed that changes in primary demand impact derived demands, limited empirical work has quantified how changes at the retail and export beef level impact farm level demands and therefore producer welfare. The goal of this study is to provide current estimates of these price transmissions.

The quantitative linking of primary retail beef demand to farm level demand has implications for the beef marketing channel. Primary beef suppliers need to understand how what happens at the retail level and in export markets impacts demand for their farm products. Promotional efforts like the Beef Checkoff Program aim to increase primary retail demand for beef. The demand impacts could reveal who benefits from programs that increase domestic and export demand. These implications are timely and should be noted in ongoing disputes around beef checkoff programs (USDA, 2014). On the other hand, negative shifts at the retail level or in export demand also impact farm level demand. For example, a food safety or alternative adverse event, such as BSE, that decreases beef demand will negatively impact farm level revenue.

Results are useful in evaluating investment opportunities and impacts of new technologies or policies. If investment is anticipated to increase retail beef demand, an analysis can be conducted using our results to determine whether the increase in demand will offset the

costs of implementing the proposed investment. Similarly, when new policies are evaluated that impact domestic or export demand for beef our results can be used to assess impacts on fed and feeder cattle producers.

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Table 1. List of Variables

Variable	Description
Q_t^L	Quantities demand and supplied of fed cattle, federally inspected steers and heifer harvested, 1000 head
Q_t^F	Quantities demanded and supplied of feeder cattle (feeder cattle placements), 1000 head
P_t^L	Demand and supply prices of fed steers, live basis, 5-market average, total all grades, $ cwt
P_t^F	Demand and supply prices of feeder steers, weighted price, Oklahoma City, $/cwt
P_t^W	Slaughter cow price, boning utility, Sioux Falls, $/cwt
P_t^C	Feed corn price, $/bu
P_t^H	Alfalfa and mixed hay price, $/ton
RDI_t	Quantity based retail demand index (1996=100)
EI_t	Quantity based export demand index (1996=100)
M_t	Food marketing cost index (1967=100)
I_t	Feeder livestock interest rate
$time_t$	Time trend
Q_t^2, Q_t^3, Q_t^4	Quarter 2, 3, 4 dummy variables
$PGDP_t^{US}$	Per capita US gross domestic product
$PGDP_t^{World}$	Per capita world gross domestic product (net US GDP)
EX_t	Real broad exchange rate index

<div align="center">

Table 2. Summary Statistics, 1996Q1-2016Q3

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| Variable	Min	Max	Mean	St. Dev.
Q_t^L	5395.00	7756.00	6722.66	557.25
Q_t^F	4226.00	7135.00	5790.41	637.43
P_t^L	35.35	70.11	45.89	7.98
P_t^F	36.67	107.75	57.03	13.89
P_t^W	16.80	48.20	27.47	6.76
P_t^C	0.92	3.14	1.66	0.59
P_t^H	43.50	83.27	58.59	11.13
RDI_t	91.81	123.63	103.93	7.22
EI_t	9.45	206.51	103.95	36.85
M_t	278.37	291.41	285.75	3.02
I_t	0.29	8.14	4.36	1.99
$time_t$	1.00	83.00	42.00	24.10
$PGDP_t^{US}$	2173.04	3899.82	3051.89	565.80
$PGDP_t^{World}$	19398.50	24133.34	22157.04	1197.99
EX_t	95.31	129.18	109.91	9.54
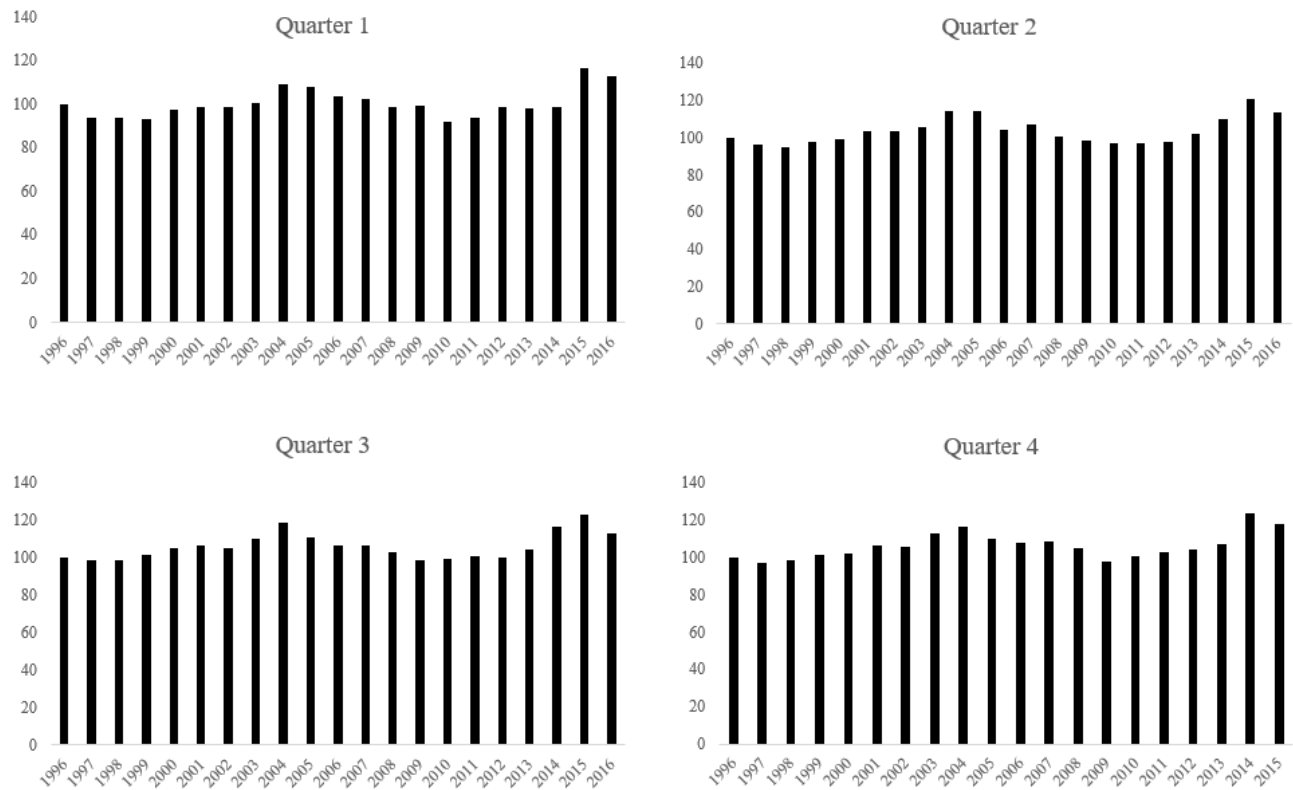
Figure 1. Quantity-based U.S. retail beef demand for 1996Q1 to 2016Q3 (1996=100)
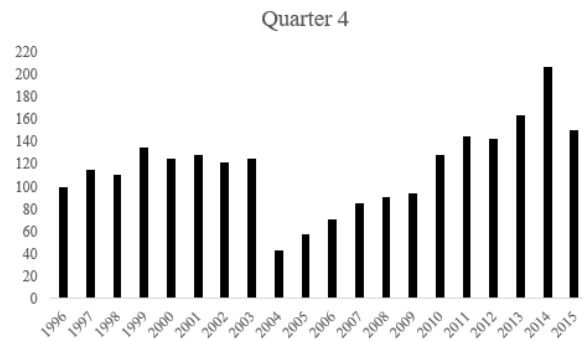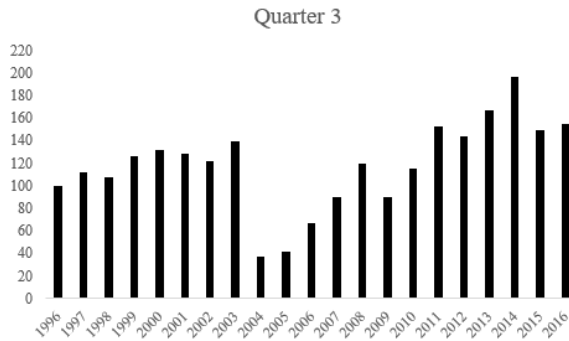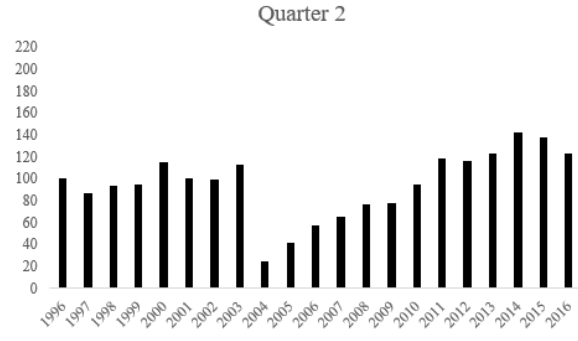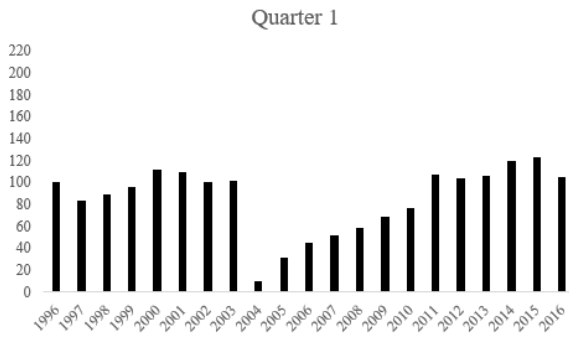
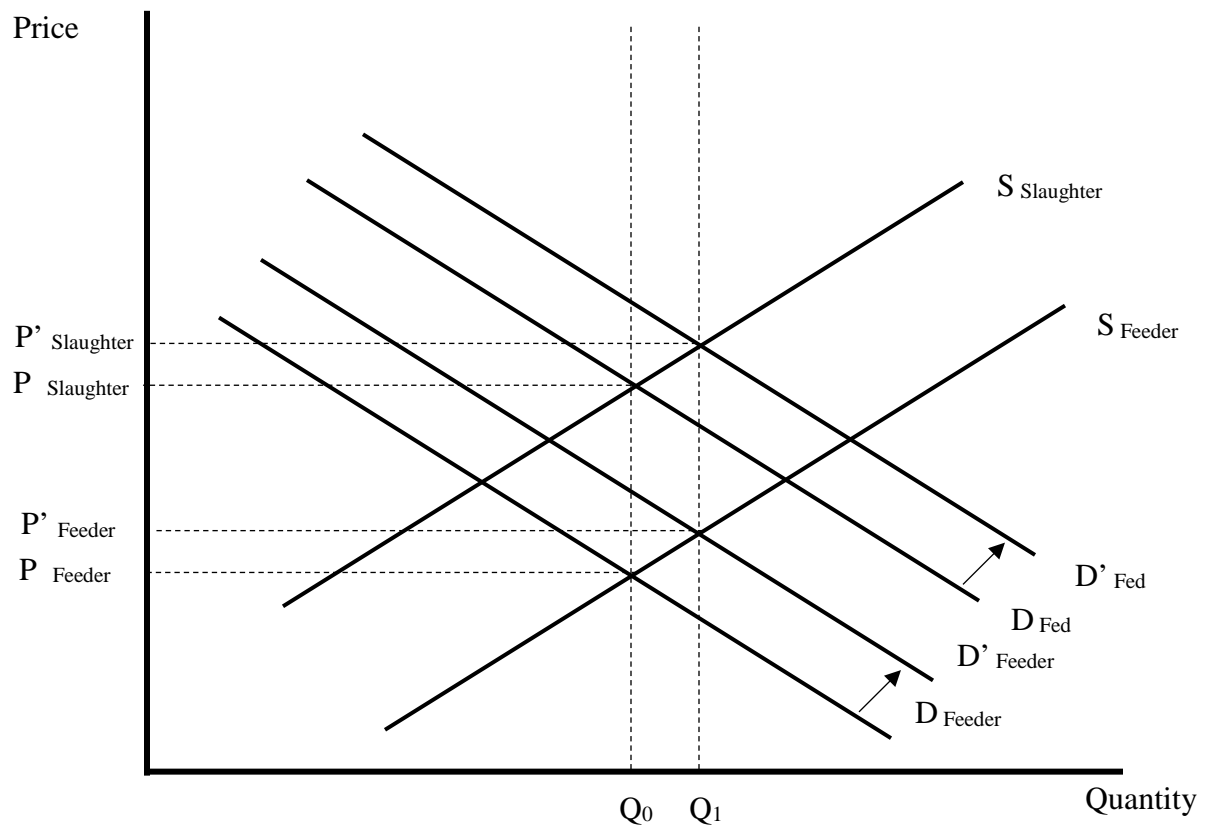**Figure 2.** Quantity-based U.S. export beef demand for 1996Q1 to 2016Q3 (1996=100).

Figure 3. Effects of increased beef demand on fed and feeder cattle prices and quantities

APPENDIX A. Data sources and notes

Variable	Description	Source
Q_t^L	Quantities demand and supplied of fed cattle, federally inspected steers and heifer harvested, 1000 head	LMIC, catsltr file, sheet C, using the sum of FI Steer Slaughter and Heifer Slaughter as number of head, and FI weight, updated 12-5-16
Q_t^F	Quantities demanded and supplied of feeder cattle (feeder cattle placements), 1000 head	LMIC, COFWTS file, sheet B, using total calves placed in US (column AU), updated 12-5-16
P_t^L	Demand and supply prices of fed steers, live basis, 5-market average, total all grades, $ cwt	LMIC, Mo180-5MktAvgFats.xls, sheet LV steers, column V "average", updated 12-6-16
P_t^F	Demand and supply prices of feeder steers, weighted price, Oklahoma City, $/cwt	LMIC, okstrhfr.xls, sheet C, using steer prices for 500-600, 600-700, 700-800, 800-900 weights. To create weighted price, multiple by percent of placements in that weight category and sum up, updated 12-6-16
P_t^W	Slaughter cow price, boning utility, Sioux Falls, $/cwt	LMIC, WklyCow-Bull.xls, sheet SF-monthly, column V (boning, 800-1200 lbs), updated 12-6-16
P_t^C	Feed corn price, $/bu	LMIC, feedpr.xls, sheet B, column C (Corn price), updated 12-6-16
P_t^H	Alfalfa and mixed hay price, $/ton	National Agricultural Statistics Service (NASS), HAY - PRICE RECEIVED, MEASURED IN $ / TON, NATIONAL, updated 12-6-16
RDI_t	Quantity based retail demand index (1996=100)	
EI_t	Quantity based export demand index (1996=100)	
M_t	Food marketing cost index (1967=100)	Contact with Howard Elitzak, Agricultural Economist, Economic Research Service, U.S. Department of Agriculture, updated 12-21-16
I_t	Feeder livestock interest rate	Kansas City Federal Reserve Bank, H.15 Selected interest rates, sheet afdr_a5, column C (feeder livestock),
$time_t$	Time trend	Where q1 1996=1, q2 1996=2, etc.
Q_t^2, Q_t^3, Q_t^4	Quarter 2, 3, 4 dummy variables	

$PGDP_t^{US}$	Per capita US gross domestic product	International Monetary Fund, https://www.imf.org/external/pubs/ft/weo/2016/02/weodata/index.aspx. click on by country groups (aggregated data) and commodity prices, clear all , then select world or United states, continue under national accounts, select GDP, current prices, US dollars, continue under select date ranges, select 1996 to 2016, left all other options at default, then prepare report download data on next page
$PGDP_t^{World}$	Per capita world gross domestic product (net US GDP)	Same as above
EX_t	Real broad exchange rate index	Federal Reserve Bank, https://www.federalreserve.gov/releases/h10/summary/indexbc_m.htm, Price-adjusted Broad Dollar Index
CPI	Consumer price index	Bureau of labor statistics, Go to http://www.bls.gov/cpi/#tables. Under database, Click on top picks (it is a star) under the first row. click on U.S. All items, 1982-84=100 - CUUR0000SA0 which is top box, Downloaded 12-5-16.
Per capita US beef consumption	Per capita U.S. beef consumption used in RDI	LMIC, sumq.xls, sheet A, column M, retail consumption, updated 1-8-17
Nominal choice beef price	Nominal choice beef price used in RDI, $/cwt	LMIC, Retmt.xls, sheet C, Column C (new series beef MO), updated 1-8-17
Export quantity	Total beef and veal+ variety meats beef, pounds	LMIC, file EXPVALUE.xls, sheet B, sum of columns B and C, in metric tons so multiply by 2204.62 to get pounds, updated 1-9-17

Export value	Total value of beef and veal + value of variety meats beef, thousands of $	LMIC, file EXPVALUE.xls, sheet B, sum of columns I and J, updated 1-9-17