

**AN ECONOMIC ANALYSIS OF THE PRICE DISCOUNT FOR
OVER THIRTY MONTHS OF AGE CATTLE**

A Thesis

by

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ABSTRACT

On December 23, 2003, the first confirmed United States case of Bovine Spongiform Encephalopathy, or BSE, was discovered in Washington State. Four major importing countries of United States beef placed import bans on this beef immediately following the emergence of BSE. Since then all four countries have lifted the bans but placed restrictions of not importing beef from cattle over 30 months of age. As a result, cattle priced on formulas or on grids are discounted if older than 30 months. The purpose of this thesis is to analyze the impacts that economic factors have upon the over thirty month discount and the relative over thirty month discount.

Two models are run, a model showing how the economic factors effect 1) the discount and 2) the relative discount. Time series modeling using the ordinary least squares regression method is employed.

Economic factors, such as prices, supplies, United States beef exports, and export restrictions, are shown to affect the discount and relative discount for cattle over 30 months of age. Supplies have the largest impact on the discount and relative discount. As supplies increase the discount and relative discount increases. United States beef exports have the next largest impact on the discount and relative discount. An increase in exports to countries that maintain age restrictions will increase the discount and relative discount, while an increase in exports to countries without age restrictions will decrease the discount and relative discount. The reopening of beef trade between the United States and South Korea is found to cause the discount to grow.

This thesis found that as supplies increase or a higher percentage of United States beef exports are imported by countries with age restrictions on beef, the discount will increase, overall decreasing the value of these older cattle. If a higher percent of United States beef exports are imported by counties that do not have age restrictions, the discount will decrease and the value of these older cattle will increase. Overall, this thesis provides insight into the factors that change the discount for cattle over thirty months of age.

DEDICATION

I would like to dedicate this thesis to my family: my parents, brother, and sister. Without your love and support I would not be where I am today. Primarily, I would like to dedicate this thesis to my parents and especially my father, Mike Reagan. I consider you to be one of the smartest and most hardworking men I have ever known. I have learned so much from you and I am proud to have you as my father. Mom and Dad, thank you for all of the work you have put into raising us kids. It has truly been a blessing to be raised in a family supported solely by production agriculture. It is because of you, Mom and Dad, that I have such a passion for agriculture and agricultural producers. Thank you for always being there and always supporting me.

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NOMENCLATURE

BSE	Bovine spongiform encephalopathy
CJD	Creutzfeldt-Jakob disease
cwt	Hundredweight
FDA	United States Food and Drug Administration
FI	Federally inspected
KPH	Kidney, pelvic and heart
LMIC	Livestock Marketing Information Center
OIE	World Organization for Animal Health
PYG	Preliminary yield grade
SRM	Specified risk materials
TSE	Transmissible spongiform encephalopathy
UK	United Kingdom
US	United States
USDA	United States Department of Agriculture
vCJD	Variant Creutzfeldt-Jakob disease

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CHAPTER I

INTRODUCTION

On December 23, 2003, the first confirmed case of Bovine Spongiform Encephalopathy, or BSE, was discovered in Washington State. Following this incident, weekly exports of United States beef fell from 13,819 metric tons of beef the week before the incident to 130 metric tons of beef by the second week of January of 2004 (LMIC, 2014). The world, effectively, closed their beef markets to United States beef. Since then the United States has been successfully working to reopen world beef markets, although there are more regulations that surround world beef trade. With the probabilities of BSE occurring in cattle under thirty months being negligible, the international standard considers beef from cattle under thirty months old to be at a low risk of contamination. Countries like South Korea, Canada and Mexico placed restrictions of not importing beef from cattle over thirty months of age, and Japan did not allow beef from cattle older than twenty months of age to be imported. These global restrictions created a new discount in beef grid pricing in the United States. Any cattle over the age of thirty months at slaughter are discounted.

Trade

In 2003, the United States was the third largest exporter of beef and veal, behind Australia and Brazil, and held 18% of the market share (Hanrahan and Becker, 2008). In response to the BSE emergence, countries closed their borders to US beef and beef byproducts. When the beef trade with these countries did begin reopening, restrictions

on age were put into place. With the closed and restricted markets, the US market share of beef fell to 3% in 2004 (Hanrahan and Becker, 2008). Historically, there are four major countries for US beef exports, Japan, South Korea, Mexico, and Canada. Prior to 2004, these four countries typically bought over 90% of the US beef exports (Leuck, Haley and Harvey, 2004). All four of these countries banned US beef immediately after the outbreak, but have reopened their markets under restrictions. Currently, Japan and South Korea still have age restrictions in place, while Mexico and Canada have relaxed their age restrictions.

Cattle Production

Cattle production in the United States follows a path and timeline from the birth of a calf to its slaughter. The path and time line is displayed in Figure 1. This path begins with the cow/calf operation. Here, the producer uses breeding stock to produce calves. Typically, a cow will yield one calf per year (hopefully). After its birth, the calf stays with its mother until it reaches weaning weight. The weaning weight will vary by operation and conditions of the operation. Some producers may want to keep the calves longer to allow them to put on more weight, or the producer may be forced to wean the calves early if the conditions of the operation are not favorable, such as very little forage for the animal. Weaning, very simply, is the removal of the calf from its mother and placing the calf on some kind of feed other than the milk from its mother. Typically, calves are weaned between six and eight months from birth and weight between 500 and 650 pounds (National Association of State Departments, 2015). In 1996, the average weaning weight was 515 pounds and the calves were weaned at 221 days after birth, or a

little over seven months (U.S Department of Agriculture, National Animal Health Monitoring System, 1997).

After the calves are weaned, they are either sold as stocker cattle to be backgrounded or sold straight to feedlots, depending on the calves' weights. The heavier calves will be sold to the feedlots. The lighter calves will be sold to the stocker and backgrounder producers. The stocker/backgrounder operations place these calves on grass, allowing them to put on more weight. These calves may stay in a stocker/backgrounder operation for 3 to 6 months until the calves reach the desired weight of 600 to 950 pounds (National Association of State Departments, 2015). Once heavy enough, these calves will be sold to the feedlots.

Feedlots, also known as feed yards or feeders, place these calves on grains and feedstuffs in order to finish them out. The calves will remain in the feedlot for 100 to 270 days, or 3 to 9 months and fed out to a market weight of 1,100 to 1,400 pounds (National Association of State Departments, 2015). After it reaches this market weight, the calf will be sold to a packing plant, or packer. In all, this process will generally take 18 to 22 months from the time the calf is born until slaughter. Another slaughter animal is a cull cow or bull. Cull cows or bulls are undesired cattle due to their age or exhibit unfavorable breeding, genetic or behavioral qualities in cow/calf operation. Often these cattle are older and may be sold straight to the packing plants rather than going through the feedlots.

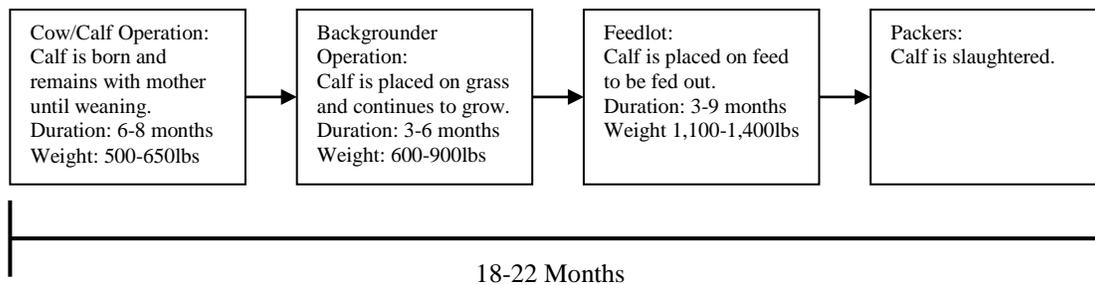


Figure 1: Path and Timeline of Birth of Feeder Calf to Slaughter

BSE

BSE is a neurological disease in cattle that is transmitted by feeding meat and bone meal from ruminant based animals to cattle. There have been four confirmed cases of BSE in the United States. The first, nicknamed the “Cow That Stole Christmas,” mentioned above, occurred on December 23, 2003 in Washington State and was a dairy cow imported from Canada. The second and third cases were United States born and raised calves in 2005 and 2006. The fourth case was found in 2012 and was an atypical BSE case. Currently, the United States is considered a negligible risk for BSE, the least amount of risk as ranked by the World Organization for Animal Health. BSE is formed from transmissible spongiform encephalopathies, or TSE, in the animal’s body through long incubation periods. Due to the length of the incubation period, an infected cow will rarely exhibit symptoms of BSE before thirty months of age.

Marketing

There are four main methods of marketing cattle as they are sold from the feedlots to the packing plants, negotiated cash, formula, forward contract, and grid pricing. Cattle may

be sold on a live or dressed basis. In the live weight pricing method, the fed steer or heifer is sold by live weight. An average price is established through either the market or by a marketing agreement between the feedlot and the packer. The weight of the calf is then multiplied by the price per hundredweight to find the sale price of the animal. This method allows the feedlots to know, with little uncertainty, the amount that they will receive for their calves, thus feedlots have less risk when selling by the live weight method. For packers, there is a high amount of uncertainty on the quality, yield and dressing percentage of the animal, placing a higher amount of risk on the packers when this method is used.

The dressed weight pricing method is very similar to the live weight pricing method. In this method, an average price that is adjusted for the dressing percentage of the animal is established. Then the average price is multiplied by the dressed weight of the calf. The dressed weight of a calf is the weight of the carcass after it has been skinned and eviscerated. With this method, risk is transferred to the feeders from the packers. Since this method relies on the dressed weight, the packer now knows the dressed weight of the animal, reducing uncertainty and risk, while the feeder will not know the dressed weight, increasing uncertainty and risk.

Grid pricing incorporates the quality of beef through monetary incentives (premiums) for higher quality beef and disincentives (discounts) for lower quality beef. The cattle's carcass is graded on quality and yield. USDA's quality and yield grades have four quality grades and five yield grades. The quality grades in descending order from highest quality to lowest quality are premium, choice, select, and standard. The

yield grades in descending order from highest yield to lowest are yield grade 1, 2, 3, 4, and 5. Grid pricing systems may have more quality or yield categories. Often choice and yield grade 3 is the base (\$0/cwt premium or discount) of the grid and animals that grade as such receive the base price. The base price is the starting price for a carcass where no premiums or discounts, or the premium and discount is equal to zero, are assigned. Premiums are awarded to carcasses that exhibit desired traits such as grading prime or scoring a yield grade of one or two, while discounts are assigned to those carcasses who exhibit undesirable traits such as grading select or standard or scoring a yield grade of four or five. Additional premiums and discounts may be assigned for other various characteristics. This method of marketing cattle provides the packers with information on the dressing percentage, quality, and yield of the carcass, reducing their risk, while the feeder's risk increases since the feeder faces more uncertainty on the final price of the animal. Grid pricing is often thought of as value based marketing because the final price of the calf displays a better notion of the value of its true characteristics.

In formula pricing, a transaction price is found by using some formula that includes an exogenous price as a reference (Ward, Schroeder, and Feuz, 2002). The exogenous price can be the boxed beef price, futures prices, cash market, last week's prices, or some other point of reference (Herrington and Tonosor, 2012). Formula pricing is typically used to determine the base price for a grid (Herrington and Tonsor, 2012).

Discount for Cattle Older Than 30 Months

One of the additional discounts in grid pricing for beef in the United States is the discount for cattle over thirty months of age. This discount emerged in January of 2004 after the first United States case of BSE. With the age regulations imposed by countries who import our beef, beef from cattle over thirty months must be able to be kept separate from beef from cattle under thirty months. This action incurs more costs and as a result, these cattle are discounted on a grid pricing system. Over time this discount has grown from -\$9.60/cwt to -\$16.42/cwt.

The relative discount is the discount as a percent of steer price. This value allows the observation of how has this discount changed over time relative to the price of cattle. The relative discount indirectly incorporates how the discount has changed through various market conditions such as tight supplies or increase demand for cattle. Over time this value has trended upwards then downwards. Figure 2 shows the variation of the discount and relative discount over time.

This research will examine economic factors that cause fluctuations in the over thirty month discount. The discount relative to a base cattle price is also analyzed. The purpose of this research is to provide insight into the economic factors that influence the discount and the relative discount change over time.



Figure 2: Over Thirty Month Discount for Cattle

CHAPTER II

LITERATURE REVIEW

BSE

Bovine Spongiform Encephalopathy is the result of a transmissible spongiform encephalopathy (TSE) agent that resembles scrapie like transmissible agents found in sheep and goats (Collee, 1990). Scrapie has been recognized as a naturally occurring disease in sheep and goats for over two centuries. This neurological disease is not recognized as a bacteria and acts differently from a virus. Upon examination of the brain of an infected animal, it is found that scrapie will cause microscopic vacuoles due to the loss of neurons. These microscopic vacuoles will resemble holes in a sponge. Other mammals, including humans, farmed mink, Mule deer, Elk, Nyala, Gemsbok, Eland, Arabian oryx, Greater Kudu and domesticated cats, can obtain a type of TSE disease (Wilesmith and Wells, 1991).

A transmissible encephalopathy is a progressive neurological disease that degenerates neuronal systems in animals in a symmetrically distributed manner (Wilesmith and Wells, 1991). Wilesmith and Wells (1991) explained that transmissible encephalopathy agents will cause “vacuolar degeneration of neurons, astrocyte reaction and amyloidogenic accumulations of an altered neuronal membrane glycoprotein.” The infectious component within a transmissible spongiform encephalopathy agent is an altered neuronal membrane glycoprotein, a mutated protein with a glycolipid membrane anchor, known as PrP^{Sc} or PrP^c (Brown and Bradley, 1998. World Organization for

Animal Health, 2010). Distribution of cells infected by a transmissible spongiform agent lie primarily in the nervous system but may also effect visceral organs (Brown and Bradley, 1998). The distribution will vary by species, route of infection and agent strain.

In BSE, the vacuolar degeneration of neurons occurs in two ways. The first way is the “microcytic vacuolation of grey matter neuropil” or neuropil in the form of grey matter is formed in the vacuoles of tiny cells (Wilesmith and Wells, 1991). Neuropil is a dense area with relatively few cells. This process causes the spongiform change. The second way vacuolar degeneration occurs in BSE is the development of a large single vacuole or multiple large vacuoles in the perikarya of neurons. The perikarya of a neuron is the cell body of a neuron. With this disease, the development of spongiform through vacuolar degeneration, the first method discussed, predominates over the development of vacuoles in the perikarya. In scrapie the opposite is found, where the development of vacuoles in the perikarya dominates over the development of spongiform.

Other than the vacuolar degeneration of neurons, infrequent occurrences of neuron degeneration, such as solitary necrotic neurons and dystrophic neurites, as well as shrunken neurons, have been observed (Wells and Wilesmith, 1995). Astrocytic reactions do occur in BSE, although the changes “are rarely as severe as observed routinely in natural scrapie” (Wells and Wilesmith, 1995). It was also found that demonstrable cerebral amyloidosis is an unusual response to BSE.

BSE attacks the neurons within an animal’s brain, brain stem and in the spinal cord. Wells and Wilesmith (1995) found that vacuolar degeneration occur in the

brainstem across all cases, whereas other parts of the brain and spinal cord vacuolar degeneration may or may not be present. The severity of vacuolar degeneration diminishes along the caudo-rostral movement of the brain, or is more prevalent and severe towards the brainstem and less present and severe towards the frontal lobe of the brain. Within the spinal cord, vacuolar degeneration are found in the cerebral, thoracic and lumbar regions. In a study, Wells and Wilesmith (1995) found that the severity of the vacuolation in the cerebral, thoracic and lumbar regions of the spinal cord is comparable to that of the medulla oblongata, indicating that “the height of the lesion profile throughout the spinal cord in BSE is comparable with that in the brainstem.” Within the brain and brainstem, the area of most severity of vacuolation is the mesencephalon followed by the medulla oblongata, while in the spinal cord, the area of most severity lies within the dorsal horns. Across the cases of BSE, the prevalence of vacuolar changes and severity remains uniform whether the animal is infected naturally through feed or by other forms of experimentation. This indicates that there is a single strain of BSE.

Wells and Wilesmith (1995) found “consistent neuronal loss only in nuclei of the vestibular complex.” Compared to a non-infected cow, approximately half of the neurons in the vestibular complex remain. The vestibular complex provides the most contribution in balance and spatial orientation for movement. Other nuclei related to movement, the caudate, red and hypoglossal nuclei, as well as the dorsal nucleus of the vagus nerve, did not show a significant loss of neurons.

BSE emerges in cattle from a transmissible spongiform agent after a long incubation period. This incubation period for clinical BSE is generally around four to six years but ranges from 20 months to 22 years (World Organization for Animal Health, 2010). Typically, BSE will not appear in infected cattle until after thirty months of age, and the last animal naturally infected with BSE younger than thirty months was in 1996 and found to be 29 months old (BSEinfo.org, 2016). During this incubation period, the infectious agent progresses to the central nervous system from the area initially infected (Wells et al., 2007). In a study conducted by Wells et al. (2007), it was found that the attack rate and the length of the incubation period depend on the dosage of infected material consumed by cattle. This study found that as the dosage of infected material increases, the attack rate increases and the incubation periods decreases. Cattle can contract BSE through the exposure of 1 mg of infected material, with an attack rate of one in fifteen animals at that level, but a 100% attack rate will occur if exposed to 100 mg of material. It was found that the average incubation period being approximately five years, naturally infected cattle were probably exposed to 100mg to 1g of infected material.

Identification of BSE first occurs through subtle changing behavioral signs. Due to these behavioral changes, many infected animals may be disposed of well before suspicions of BSE occur (World Organization for Animal Health, 2010). BSE cannot be confirmed in a live animal, but rather, confirmation is achieved post-mortem by examination of sections of the brain, brain stem or spinal cord. The clinical signs of BSE of live animals include changing behavior, temperament, hyper-reactivity and

incoordination. For dairy cows, the first signs are typically reluctance to entering the milking parlor and kicking vigorously during milking, and for dry cows, the first signs are incoordination of the hind-limbs and weakness. Signs of nervousness, loss of rear movement, and heightened sensitivity to touch and sound are commonly reported. Physical characteristics of an infected cow may include low head carriage, an extended neck, arched back, wide-based hind limbs, and a head tremor. Cattle in the pasture often exhibit an abnormal gait that is typically confined to the hind legs. As the disease progresses, locomotive movements worsen and weakness grows, leading to increased amount of falling and resting periods for the animal.

In the 1980's, it was confirmed that BSE can be identified solely by evaluating a single section of the medulla oblongata, allowing for easier identification of the disease by only removing a single part of the brain rather than the whole brain (World Organization for Animal Health, 2010). "Rapid" tests using *in-vitro* methods are now performed as a screening tools for active surveillance of BSE and provides a preliminary diagnosis of the disease (World Organization for Animal Health, 2010). These tests aid in identifying potentially infected animals, but examination of the nervous system must be performed to confirm the disease.

The first confirmed case of BSE in domesticated cattle occurred in November of 1986 in the United Kingdom (Wilesmith and Wells, 1991). It is estimated that the BSE epidemic in the UK actually began in April of 1985. The common belief is that BSE originated from scrapie or a "scrapie-like" agent exposed to cattle through meat and bone meal from ruminant animals (Collee, 1990. Wilesmith and Wells, 1991. Brown et

al., 2001). The use of meat and bone meal for a protein enriched food source for livestock was practiced for decades prior to the BSE epidemic in UK. Around 1980, the methods of rendering meat and bone meal changed, creating the belief that the altered process allowed scrapie agents to survive and be exposed to cattle (Wilesmith and Wells, 1991. Brown et al., 2001). The exposure of the infected meat and bone meal is believed to occur in 1981 or 1982 and infected mainly the calves rather than the cows exposed (Wilesmith and Wells, 1991). The long incubation period of BSE and the practices of manufacturing feedstuff for cattle derived from ruminants in the UK allowed for meat and bone meal to be produced from cattle infected with BSE. This caused more cattle to be infected, spurring the BSE epidemic in the UK. The UK Government issued the over 30-month rule in March of 1996 (Smith and Bradley, 2003). This rule required that meat from cattle over thirty months of age “be de-boned and the obvious nervous and lymphatic tissue removed and treated as SRM” or specified risk materials (Smith and Bradley, 2003).

After the emergence of BSE in 2003 in the United States, the United States Food and Drug Administration (FDA) would develop their own 30-month rule. In October, 2005, the FDA proposed the rule that the brains and spinal cords from cattle at least thirty months of age cannot be used in food or feed of all animals (U.S. Department of Agriculture, Food and Drug Administration, 2008).

Creutzfeldt-Jakob disease (CJD) and Kuru are the human equivalents of BSE found in cattle. Kuru is an encephalopathy that can be transmitted orally or through artificial inoculation (Holt and Phillips, 1988). This disease was found in 1957 in the

South Fore tribe of Papua New Guinea (Collee and Bradley, 1997). This tribe practiced endocannibalism, or cannibalism of members within their tribe, where the women and young children were exposed to brains, internal organs and intestines of the deceased tribe member. It is believed that this disease emerged in this tribe after tribe members practiced cannibalism on an infected human.

CJD is a form of spongiform encephalopathy (Collee, 1990). Scrapie is not a human pathogen and as a result humans cannot obtain CJD by consuming animals infected with scrapie (Brown et al., 2001). Although, transmissible spongiform encephalopathies, like BSE, may not be transmitted from one species to another directly, they may be transmissible from one species to another by going through a third species. BSE, for example, could not infect hamsters until the disease had passed through mice. This led to an increased concern that BSE could be transmitted to humans, even though it is believed that BSE was originally contracted from scrapie.

From May 1995 to March 1996, a collection of ten cases of CJD in people younger than 50 with amyloid plaque being present emerged in the UK (Brown et al., 2001). These two characteristics are uncommon in sporadic cases of CJD. So uncommon that amyloid plaque only occurs in 5% to 10% of sporadic cases of CJD. The clinical and neuropathological features found in these ten cases differed from other cases of CJD found in young people across Europe. A report on these ten cases emerged in March of 1996. The report concluded that a variant of CJD (vCJD) had emerged, probably caused by exposure to BSE. Since this report, it has been confirmed that the

pathologic agent found in BSE has the same distinctive biological and molecular biological features as the pathologic agent found in vCJD.

Muscles from any animal have never been found to contain the infectious agents of spongiform encephalopathy and the development of vCJD could not have come from the consumption of beef (Brown et al., 2001). Rather, the consumption of beef products containing nervous system tissue infected with spongiform encephalopathy agents is likely the cause.

BSE: OIE and 30 Month Old Cattle

The World Organization for Animal Health (OIE) develops recommendations for the control and confinement of animal diseases. For BSE, OIE lists three rankings of risk, undetermined risk, confined risk and negligible risk. On May 22, 2007, the United States was recognized by OIE as having controlled risk (Hanrahan and Becker, 2008). This ranking was upgraded to negligible risk at the 81st General Session of the World Assembly of Delegates of the World Health Organization for Animal Health held May 26-31, 2013 (World Organization for Animal Health, 2013). With BSE, OIE develops the requirements to identify a level of risk for a country and the different recommendations for each level of risk of BSE.

A country wishing to receive or maintain a status of controlled or negligible risk must comply with four criteria set forth by OIE (World Organization for Animal Health, 2013). The four criteria are 1) conducting a risk assessment identifying threats of BSE, 2) perform an on-going awareness program on BSE symptoms to those involved with cattle in target sub-populations, 3) notifying OIE and investigating any cattle showing

signs of BSE, and 4) examining the of brain or other tissue of animals as designated by the recommendations under the surveillance for BSE in that country. Within the risk assessment, two individual assessments are conducted, the release assessment and the exposure assessment. The release assessment focuses on the likelihood that BSE contaminated products has entered the country, and if risk is identified within this assessment, then the exposure assessment is conducted to determine the likelihood of cattle being exposed to these contaminated products.

For a country to be distinguished between controlled and negligible risk, certain conditions within the criteria listed above must be met. With negligible risk, a country must have conducted the risk assessment and the appropriate measures have been taken, and Type B surveillance must be in place (World Organization for Animal Health, 2010). Also, a country must have either not had a confirmed case of BSE or if there was a confirmed case, prove that the infected animal was imported from another country and has been properly disposed of. A country with a case of BSE from a domestically raised animal may be eligible to be considered negligible risk if any and all cases of BSE within the country were born more than eleven years before the status change, and any possibly effected animals associated with the confirmed case have been properly controlled and disposed of properly. It must also be proven that the practice of feeding meat and bone meal and greaves, derived from ruminants, to cattle has not been performed in the eight years prior to the status change, and criteria 2 and 4 listed above must have been implemented for at least seven years.

For a country to be identified as controlled risk, the same conditions must be met as with negligible risk with some changes. The first change is that the country must perform Type A surveillance rather than Type B (World Organization for Animal Health, 2010). If a country has never had a confirmed case of BSE or has proven that all cases of BSE were imported, it will be classified as controlled risk if it cannot demonstrate that for eight years the practice of feeding meat and bone meal and graves, derived from ruminants, to cattle has not occurred. Also, criteria 2 and 4 listed above must be implemented for at least seven years. If there is a confirmed case of BSE, then for the country to be considered controlled risk, the country must demonstrate that meat and bone meal and graves, derived from ruminants, has not been fed to cattle, and any possibly effected animals associated with the confirmed case have been properly controlled and disposed of properly.

Undetermined risk is placed on any country with which the risk of BSE in that country has not yet been determined or the criteria is not met to be classified as controlled or negligible risk (World Organization for Animal Health, 2010).

There are two types of surveillance of BSE in countries, Type A and Type B, as mentioned above (World Organization for Animal Health, 2010). Surveillance is designed to detect and monitor the evolution of BSE, and monitor the effectiveness of feed bans and other risk mitigation practices. Type A surveillance samples approximately twice as many animals as Type B surveillance. Four subgroups of cattle are identified by OIE for surveillance, 1) cattle over thirty months old with symptoms of BSE, 2) cattle over thirty months old identified as having severe movement disabilities

or identified as emergency slaughter and downer cattle, 3) cattle over thirty months old found dead on the farm or in transport, and 4) cattle over thirty-six months old at routine slaughter. More weight is placed on sampling cattle from the first subgroup and decreases through the movement from subgroup one to four.

OIE has set recommendations for countries who wish to import beef from countries identified as negligible, controlled and undetermined risk. The recommendations set for a country identified as negligible risk carry over to countries with controlled and undetermined risk, although, these countries have more recommendations in place (World Organization for Animal Health, 2010). For a country identified as controlled risk, the additional recommendations revolve mainly around the additional products that should not be exports. For cattle over thirty months of age, the brain, eyes, spinal cord, skull, vertebral column, and meat mechanically separated from the skull or vertebral column should not be exported or allowed to potentially contaminate other products meant for export. Gelatin and collagen prepared from bones may not be produced using the skull or vertebral column from cattle over thirty months and the bones that are used are subjected to additional processes. The tonsils and distal ileum from cattle should not be exported regardless of age. Cattle meant for export may not be stunned using a pithing process or by injecting compressed air or gas into the cranial cavity. Undetermined risk recommendations are the same as those for controlled risk with the exception that the age limit is twelve months rather than thirty months for their products. These recommendations are set to attempt to stop any spread of BSE from country to country and increase food safety for beef. These recommendations also

place a higher cost on cattle over thirty months old due to the additional handling processes and there is less demand for these cattle due to the increased food safety risk.

BSE: Trade After the Emergence of BSE in the United States

With the emergence of BSE in the United States in 2003, the beef trade market became severely disrupted. In 2003, the US held 18% of the world's beef and veal market share and that value fell to 3% in 2004 (Hanrahan and Becker, 2008). The United States experienced an 82% drop in beef exports as exports fell from 783,000 metric tons in 2003 to 139 metric tons in 2004 (LMIC, 2015). In 2003, Japan, South Korea, Mexico, and Canada accounted for 33%, 29%, 26% and 6% of the US beef exports respectively (LMIC, 2015). These four countries accounted for over 94% of the exports in 2003.

In December 2003, immediately following the emergence, Japan, South Korea, Mexico, and Canada would begin to ban US beef. By the start of the second week of January in 2004, US beef exports to these four countries had ceased and bans were successfully put into place. In 2004, Japan, South Korea, Mexico, and Canada accounted for 0%, 0%, 88% and 8% of the US beef exports respectively (LMIC, 2015). During this year, Mexico and Canada lifted their bans and these two countries accounted for 96% of the US beef exports (LMIC, 2015). Figure 3 shows the change in total volume exports for each country.

Since 2004, Japan and South Korea have lifted their bans and all four countries have reopened their markets to US beef trade, but have set restrictions. The restrictions set forth by these importing countries revolved around age, specifically thirty months of age. With OIE placing export recommendations on cattle over thirty age of months from

a country that has experienced a case of BSE and the fact that BSE is negligible in cattle under this age, the thirty months of age restrictions have become the benchmark for policies surrounding the world beef market.

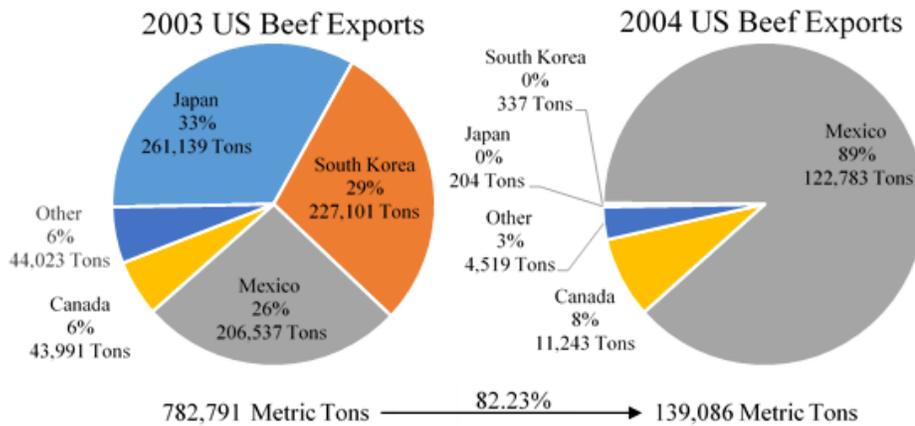


Figure 3: US Beef and Veal Imports and Exports (2003 to 2004)

In 2002, Canada represented a third of US beef imports which accounted for 4% of the total US beef consumption (Leuck, Haley and Harvey, 2004). Live cattle from Canada accounted for 4.6% of the total cattle and calves slaughtered in the United States. The US beef and live cattle exports to Canada are 20-25% of the volume imported by the United States from Canada. US beef and live cattle trade would be greatly disrupted in 2003 with the emergence of BSE in Canada and the United States.

On May 20, 2003, the announcement came that Canada had confirmed its first case of BSE in Alberta (Leuck, Haley and Harvey, 2004). Following this news, the United States, as well as other major markets for Canadian beef, announced a ban on all

Canadian cattle and beef products. The ban placed by the United States was lifted on August 8, 2003, but under the restrictions of only importing “deboned beef from certified cattle less than 30 months old” (Leuck, Haley and Harvey, 2004). In July 2005, the Canadian live cattle market was reopened under the restrictions of only importing cattle under the age of thirty months.

Following the emergence of BSE in the United States, Canada banned US beef temporarily, and the ban was lifted in January 2004. Canada placed similar restrictions on US beef as the United States had placed on Canadian beef. Canada would only import deboned beef from cattle younger than thirty months and live cattle under thirty months for immediate slaughter (Leuck, Haley and Harvey, 2004. Southard, 2004). Annual beef exports to Canada fell by 74.44% from 2003 to 2004 (LMIC, 2015). In June, 2006, Canada reduces the restrictions to allow beef from all ages to be imported from the United States (LeBlanc, 2008).

Trade with Mexico consists of the United States importing live cattle meant for feedlots and then exporting beef back to Mexico. In December 2003, following the emergence of BSE, Mexico placed a ban on US beef. Mexico would lift in ban in early March 2004, but would restrict imports to only allowing deboned beef from cattle younger than 30 months of age (Southard, 2004). Annual beef exports to Mexico fell by 40.55% from 2003 to 2004 (LMIC, 2015). Good news for this market would come on April 30, 2014. On this day, Mexico relaxed their import restrictions and began to allow US beef and beef products from cattle of all ages (GAIN, 2014).

In 2003, beef imports accounted for 73% of total South Korean beef consumption with the United States supplying two-thirds their imported beef (Giamalva, 2013). South Korea, like Canada and Mexico, banned US beef following the emergence of BSE in the United States. Annual beef exports to South Korea fell by 99.85% from 2003 to 2004 and beef imports for South Korea fell by 52% as a result of this ban (LMIC, 2015. Giamalva, 2013). The ban was first lifted on September 11, 2006 under the restrictions of only allowing boneless beef from cattle under thirty months of age (Hanrahan and Becker, 2008). In October 2007, South Korea reinstated the ban on US beef when bone fragments and “unacceptable dioxin levels” were found in the meat (Hanrahan and Becker, 2008). South Korea would reopen their market to US beef on April 18, 2008 under the restrictions of only allowing boneless and bone-in beef from cattle under thirty months of age (Giamalva, 2013). Originally, South Korea had agreed that after the United States has met certain criteria set by the South Korean government, they would begin to import US beef from cattle of all ages (Hanrahan and Becker, 2008). The South Korean consumers, concerned for food safety, rejected this part of the agreement enough that it was never put into place (Hanrahan and Becker, 2008). Currently, beef exported to South Korea from the United States are still restricted to be produced from cattle under thirty months of age.

The Japanese government announced on September 11, 2001, that a confirmed case of BSE was discovered within their country. (Leuck, Haley and Harvey, 2004). On the heels of this announcement, Japanese beef consumption fell by 60%. US beef exports fell from an average of 90 million pounds per month to 30 million pounds in

November and 8 million pounds in December of that year. This drop in exports accounted for an 8% decline in total exports for US beef. From January 2002 to December 2003, exports to Japan were on the rise, but with the emergence of BSE in the United States in December 2003, Japan placed a ban on all US beef.

Japan first reopened its market to US beef in December, 2005 under the restriction of only allowing beef products from cattle under than twenty months of age (Hanrahan and Becker, 2008). US beef was banned again on January 20, 2006 after vertebral column bone fragments, a restricted item, were found in several boxes of US beef. On July 27, 2006, six months after reclosing the market, Japan would reopen the market under the same twenty month age restrictions. Since then, the United States has been working with Japan to reduce these restrictions, and in February of 2013, Japan eased the restrictions to allow beef from cattle under thirty months of age, rather than twenty (Strom and Tabuchi, 2013).

Beef Trade

The United States both imports and exports beef. Most exported beef is “grain-finished, and marketed as higher-value cuts,” and the imported beef is “lower-valued, grass fed beef destined for processing, primarily as ground beef” (Melton, 2012). Historically, the United States has been a net importer of beef and veal by volume (U.S. Department of Agriculture, Economics Research Service, 2016). Since 2002, there have been only four years, 2010 through 2013, where the United States has been a net exporter of beef and veal. Figure 4 shows the graph of US beef and veal exports and imports.

Beef exports were at an all-time high in 2003, and were rising despite the lack of demand for beef in Japan. In 2004, exports plummeted in response to the emergence of BSE. From 2004 to 2011, annual exports for the United States grew by over 505% before peaking in 2011 at a record 2.8 billion pounds of beef and veal (USDA-ERS, 2016). Annual exports decreased to 2.3 billion pounds in 2015, an 18.6% reduction from the 2001 record. Japan, South Korea, Mexico and Canada remain the major markets for US beef exports despite their trade restrictions. Since 2010, these four countries have accounted for 64% to 70% of the total US beef and veal exports.

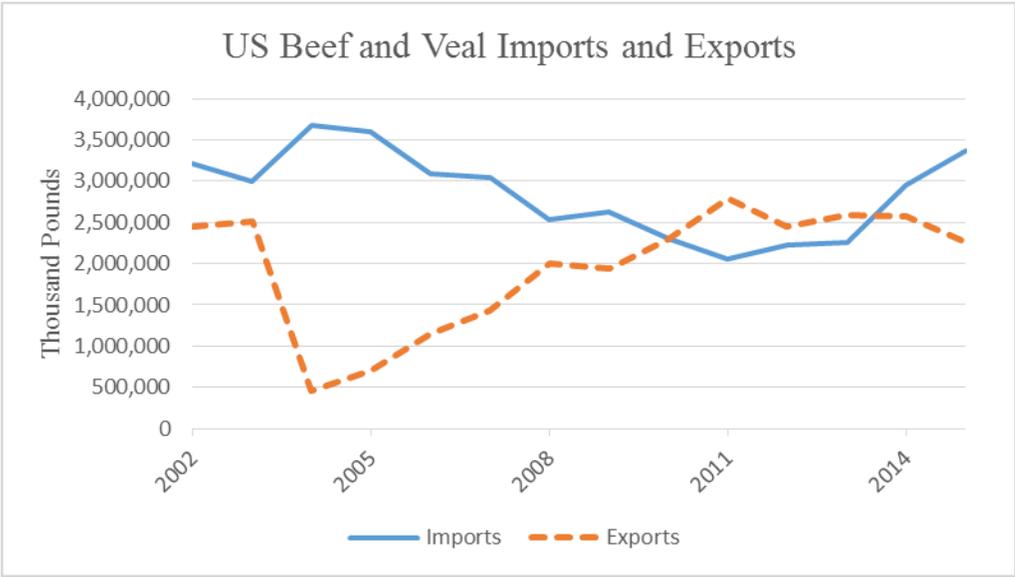


Figure 4: US Beef and Veal Imports and Exports

Beef and veal imports hit an all-time high in 2004 at 3.7 billion pounds and declined by 44.1% to a low of 2.06 billion pounds in 2011 (USDA-ERS, 2016). Imports have since increased to 3.4 billion pounds in 2015. Four main countries, Australia, Canada, New Zealand and Mexico, dominate the United States beef and veal import market, accounting for over 85% of total imports since 2010.

Grades and Standards

The United States Department of Agriculture (USDA) has five classes of cattle type, steers, bullocks, bulls, heifers, and cows, which are classified by maturity and sex (U.S. Department of Agriculture, Agricultural Marketing Service, 2016). Male carcass classifications are steers, bullocks, and bulls. The carcass is classified as a steer if it possesses a relatively small “pizzle muscle” (attachment of the penis) and “pizzle eye,” whereas the bullocks and bulls will have a larger “pizzle muscle” and “pizzle eye.” The distinguishing characteristic between a bullock and bull is the skeletal maturity of the animal. Female carcass classifications are heifers and cows. The distinguishing characteristic between the female classifications is the carcass of a heifer will have the udder intact and a cow’s udder will be removed (U.S. Department of Agriculture, Agricultural Marketing Service, 2016).

Under the USDA, there five maturity groups, A-E (Hale, Goodson, Savell, 2013). These maturity groups break up cattle by their physiological age. The physiological age a cow is found by evaluating physical characteristics of its carcass, as opposed to using the cow’s chronological age. Bone characteristics, ossification of cartilage, and color and texture of the ribeye muscle are used to determine physiological age in cattle.

Relatively more weight is placed on the bone characteristics and ossification of cartilage because other factors than age can affect the appearance of the meat. As cattle age and progress through the maturity groups from A (youngest) to E (oldest), cartilage on the thoracic buttons become harder and more ossified. Cattle grading in the A maturity class will have rounder and redder ribs, but as the animal progresses to grade C, the ribs begin to turn white, and by maturity grade E, the ribs are wide and flat.

The estimated ages of cattle within these five maturity groups are as follows; grade A cattle are approximately 9-30 months old; grade B, 30-42 months; grade C, 42-72 months; grade D, 72-96 months; and grade E cattle are older than 96 months (Hale, Goodson and Savell, 2013). The thoracic buttons are key determinants of the maturity grade within cattle. These buttons begin to ossify at the age of thirty months. Cattle are considered grade B maturity if the percentage of ossification of these buttons are from 10% to 35%, and as the percentage of ossification increases to 35%, 70%, and 90% then the cattle maturity grade will increase to C, D, and E respectfully.

The texture of grade A maturity cattle is classified as “very fine” whereas the cattle grading B, C, D and E, are classified as “fine,” “moderately fine,” “slightly coarse,” and “coarse,” respectfully (Hale, Goodson and Savell, 2013). The color of the meat changes from “light cherry-red” in grade A maturity to “dark red to very red” in grade E.

The 2005 National Beef Quality Audit found that 97.05% of the animals sampled were grade A maturity, 1.72% were grade B maturity, and the rest were grade C, D or E maturity (Garcia et al., 2008). Animals identified as cows and bullocks, which

accounted for 0.1% of the sample, presented older maturity scores than the 99% of the sample that were steers and heifers. In this same audit, only 19.4% of the grade A maturity animals sampled met the more restrictive age requirements set forth by the Japan government at the time for importing US beef.

The USDA identifies eight types of quality grades for beef, Prime, Choice, Select, Standard, Commercial, Utility, Cutter and Canner, with the four most commonly known grades being Prime, Choice, Select, and Standard. The quality grades identify the factors that influence the palatability of the meat, such as “carcass maturity, firmness, texture and color of lean, and the amount and distribution of marbling within the lean” (Hale, Goodson and Savell, 2013). The two main factors that are considered when determining the quality grade of a carcass are the degree of marbling and maturity of the carcass. Marbling is the amount of intramuscular fat, the fat dispersed within the meat, and is considered a more important factor than maturity when determining quality. The degree of marbling is evaluated in the ribeye between the 12th and 13th rib. Cattle grading prime are classified as having “slightly abundant” to “abundant” degree of marbling, choice cattle have “small” to “moderate” marbling, select cattle have “slight” amount of marbling, and standard cattle have no marbling to “traces” of marbling (Hale, Goodson and Savell, 2013). The higher the marbling in beef, the increased juiciness and flavor of the beef. As a result, Prime carcasses have the highest palatability of meat and palatability of the meat decreases through the lower grades from choice to select to standard. Other factors that affect the palatability, including color and texture, change over time, causing maturity to be the second factor influencing quality grades.

Steers and heifers carcass grades can be assigned to any of the eight quality grades, whereas cows cannot grade Prime, but may grade any of the other seven grades (U.S. Department of Agriculture, Agricultural Marketing Service, 2016). Bullocks may grade Prime, Choice, Select, Standard and Utility, and a bull may only receive a yield grade. Only young cattle, cattle in the maturity grade A or B, are eligible for the Prime, Choice, Select, or Standard quality grades. Older cattle in the maturity grade of C, D, or E, and are not eligible for Prime, Choice, or Standard, but can be graded Commercial quality. Carcasses from cattle of all ages may be graded Utility, Cutter or Commercial.

Cattle grading B maturity must possess a higher amount of marbling than that of cattle grading A maturity to be considered the same quality grade. Both maturity and quality grades are divided up into individual sections and assigned a value system. Maturity is divided into the five age groups with 100 subunits within each age group (Hale, Goodson and Savell, 2013). Maturity A ranges from A00-A100 and B maturity ranges from B00-B100. With quality, there are eleven marbling scores divided into 100 subunits. For example, with prime quality, the valuation is divided into Abundant 00-100, Moderately Abundant 00-100 and Slightly Abundant 00-100. When determining the final quality score, the maturity score will be added to the marbling score. Due to this method of determination, a grade B maturity must possess at least modest amount of marbling to be considered choice, but grade A maturity may only have a small amount, and a grade B maturity animal with slightly abundant marbling may be considered choice, but a grade A animal with the same amount of marbling will be considered prime (U.S. Department of Agriculture, Agricultural Marketing Service, 2016).

The USDA identified five main yield grades in beef, grades 1, 2, 3, 4, and 5, that “estimate the of boneless, closely trimmed retail cuts from the high-value parts of the carcass-the round, loin, rib, and chuck” while also indicating the “total yield of retail cuts” (Hale, Goodson and Savell, 2013). The highest yielding carcass will be classified as yield grade 1, and yields from a carcass will decrease as the grades increase to 2, 3, 4 and 5. Four areas are examined when determining yield grade, the amount of external fat, hot carcass weight, amount of kidney, pelvic and heart fat (KPH fat) and size of ribeye muscle. Fat deposits in and around different areas of the carcass, such as the ribeye, kidney, pelvic and heart regions, largely affect the yield grade. The higher the amount of fat, the lower the yield grade, so yield grade 1 will exhibit the least amount of fat, and yield grade 5 will exhibit the most.

Calculating the final yield grade begins with evaluating the amount of fat, in inches, opposite of the ribeye (Hale, Goodson and Savell, 2013). The carcasses are given a calculated preliminary yield grade (PYG) where for every tenth of an inch of fat in this area, .25 is added to a base of 2 to determine this preliminary grade. The next step in calculating the yield grade is to adjust the PYG based on the hot carcass weight. If the carcass is 600 pounds, then the PYG will not be adjusted, but for every 25 pounds over 600, 0.10 is added to the PYG and for every 25 pounds under 600, 0.10 is subtracted from the PYG. The third step is to adjust the PYG by the percentage of KPH fat in the carcass. For every 1% difference in KPH fat over 3.5%, then 0.20 is added to the PYG, and the opposite happens for every 1% difference in KPH fat under 3.5%. The last step is to adjust the PYG by the size of the ribeye. For every 1.0 square inch over

11.0 square inches of ribeye, 0.33 will be subtracted from the PYG, and the opposite will happen for every 1.0 square inch difference below 11.0 inches. For example, if a carcass had 0.3 inches of fat opposite of the ribeye, weighed 500 pounds, had 3.0% KPH fat, and a ribeye size of 12.0 square inches, the following score would be calculated:

$$[2.0+(.3*.25)]+[((500-600)/25)*.10]+[(3.5-3.0)*.2]+[(12.0-11.0)*.33]=2.075$$

The final yield score of this carcass would be 2.075.

Cattle grading B maturity and older receive the over thirty month discount if sold on a grid or in a value based marketing system due to their age. As cattle age to grade B maturity or older, the possibility of BSE occurrence increases as well as the quality of the meat decreases. As mentioned above, as cattle age, the meat becomes darker and coarser, decreasing palatability, and decreasing the quality of the beef. The decreased quality of grade B maturity and the limited export market of grade B maturity leads to the over thirty month discount.

Marketing System

Fed cattle are sold to packers under various pricing and marketing systems, including live weight pricing, dressed weight pricing, dressed weight and grade pricing, formula pricing, and grid pricing. Prior to the 1990s, the prevailing fed cattle pricing method was average pricing, or all of the cattle receiving an average price per hundredweight (\$/cwt.), such as live weight or dressed weight pricing (Johnson and Ward, 2006). As beef demand relative to pork and poultry declined in the 1980s and 1990s, the industry began to focus on improving the quality of beef, prompting a change to more value

based marketing systems like grid pricing (Johnson and Ward, 2006. McDonald and Schroeder, 2003).

A survey of feedlots found that in 1996, 97% of the respondents engaged in live or dressed weight marketing, decreasing to 87% of the respondents in 2001, and 70% expected to engage in this type of marketing by 2006 (Schroeder et al., 2002). The percentage of cattle marketed under live and dressed weight marketing was 82% in 1996, 53% in 2001, and it was expected to be 33% in 2006. Alternatively, the percentage of cattle marketed using a grid increased from 16% in 1996 to 45% by 2001, and was expected to increase to 62% in 2006. The respondents' motives for switching to more grid price marketing is the ability to obtain quality and yield premiums, as well as obtain carcass data.

Live weight pricing is when a pen of cattle is sold based on their live weight using an average price (Anderson and Zeuli, 2001). This average price, a price per hundredweight, is determined before the slaughter of the animals and based on an estimated average carcass quality. Total revenue for a pen of cattle sold under this method is easy to estimate since a known weight and a known price are the only factors determining revenue. A pitfall to this method is that cattle are receiving an average price rather than receiving the actual "value" of the animal, so higher quality cattle receive less than what their true market value should be and lower quality receive more (Fausti, Feuz, and Wagner, 1998).

Dressed weight pricing is when a pen of cattle are sold based on their dressed weight using an average price. As with live weight, the price is by hundredweight, is

determined before slaughter, and is based off of the estimated quality of a pen (Fausti, Fez and Wagner, 1998). This method of cattle marketing is very similar to live weight pricing, with the differences being the average price is adjusted for the hot carcass weight and cattle are sold by the dressed weight rather than the live weight. Total revenue for a pen of cattle is then a function of the dressed weights of the animals and the dressed price.

Dressed weight and grade pricing is a value based marketing strategy. This cattle marketing method includes carcass quality, yield and dressed weight (Fausti, Feuz and Wagner, 1998). With this method, the packer sets the base price for a Choice, yield grade 3 carcass. Discounts are placed on the cattle that do not meet this standard, but cattle that surpass this standard do not receive a premium. This causes the dressed weight and grade pricing method to be mainly discount based. This strategy is used on the pen level, rather than evaluating each animal on an individual basis.

Formula pricing refers to calculating a price using a formula that incorporates an external price as a reference (Ward, Feuz and Schroeder, 1999). The external price may come from different sources, such as plant averages or a market price, and may be from different beef market levels, such as live weight cash market prices or futures market prices. Formula pricing is often used to as the base price in grid pricing, although this is not always the case.

Grid pricing is a form of value based marketing that incorporates premiums and discounts when calculating the final price of an individual animal. Grid pricing begins with the base price. Often this base price is for a Choice, yield grade 3 carcass. Cattle

that exhibit higher quality features, such as grading Prime or yield grade 1 or 2, earn a premium added to the base price. A discount is subtracted for cattle that exhibit lower quality characteristics such as grading Select, Standard or yield grade 3 or 4. The summation of the premiums and discounts are often represented in a grid, giving this marketing method its name. An example of a typical grid is displayed in Figure 5.

Quality Grade	Yield Grade							Other Factors
	1-2	2-2.5	2.5-3	3-3.5	3.5-4	4-5	>5	Over Thirty Month
Prime	23.78	21.07	20.96	18.05	18.05	8.33	3.31	-16.42
Choice	5.73	3.02	2.91	0	0	-9.72	-14.74	
Select	-.49	-3.2	-3.31	-6.22	-6.22	-15.94	-20.96	
Standard	-13.69	-16.4	-16.51	-19.42	-19.42	-29.14	-34.16	

Figure 5: An Example of a Beef Price Grid (\$/dressed cwt.)

The base price of a grid may be determined from a number of different price references, including specific market-reported prices, plant average prices, boxed beef cutout prices, futures market prices, negotiated prices and formula prices (Feuz, 1999). Plant average prices are adjusted for the type of cattle being slaughtered in a particular plant and vary from plant to plant. By using plant average pricing as a base price, the value of the animal is now tied to the type of cattle slaughtered at a particular plant

rather than the value being based solely on merits of the carcass and the market. A study conducted by Ward and Lee (1999) found, that on the same day, the base price based off of plant averages for four different packing plants varied over \$2.17/cwt or over \$16/head. When the base price was tied to a market price, it was found that the base price varied over \$2.00/cwt over the course of a week.

Grid pricing is designed to improve overall beef quality by sending signals to producers through monetary incentives encouraging them to provide higher quality beef. Research has been conducted analyzing the impact of these price signals. Feuz (1999) compared three different grids in a study. Two of these grids used plant averages as the base price and the third used an adjusted USDA Choice-Select price spread as the base prices. The results showed that these different grids yielded different premiums and discounts, and that the premiums and discounts changed over time within each grid. Price signals from individual carcass qualities were also evaluated. This study found that marbling, fat thickness, and carcass weight had a significant impact on the premiums and discounts received. Forristall, May and Lawrence (2002) found that at low Choice-Select spreads, net revenue was most impacted by hot carcass weight, but at high Choice-Select spreads, marbling was the most impactful. Johnson and Ward conducted studies in 2005 and 2006 on this topic. The 2005 study found that weight accounted for 61% to 71% of the variation in cattle's value, leaving 29%-39% of the variation coming from the carcass quality characteristics (Johnson and Ward, 2005). On average, 18% of the variation in the value of the animal was a result of carcasses quality grade, 9% from the yield grade and 7% from a light/heavy discount. After producing a

sensitivity analysis on the same study, Johnson and Ward (2005) found that changes in quality and yield discounts effect price signals more than premiums. The 2006 study found that for the top one-third quality of the cattle, 72% to 92% of the variation in the grid was caused by weight, and for the bottom one-third only 39% to 56% of the variation in the grid was caused by weight (Johnson and Ward, 2006). These studies indicate that weight sends the strongest signal, followed by carcass quality and yield premiums and discounts, and that discounts send stronger signals then the premiums

Studies surrounding profit associated with grid pricing have also been conducted. A study by Feuz, Fausti and Wagner (1993) found that profits were lowest under live weight pricing, and greatest under dressed weight pricing, although the difference between profits from dressed weight pricing and value based pricing were not statistically significant. Profit variance for value based marketing was the highest, followed by dressed weight and live weight respectfully. In this study, quality grade was the most important factor in determining profits when marketed on a value based system. Greer and Trapp (2000) found that under a grid pricing system, profit is maximized if cattle are fed out for an average of 141 days, whereas if the cattle are sold using live weight pricing, profit is maximized at an average of 200 days on feed. It was found that profits from cattle sold on a grid first “increase at an increasing rate, then increase at a decreasing rate, then stay in a narrow window for several weeks before profits begin falling” (Greer and Trapp, 2000). Profits from cattle sold under average pricing follow a relatively flat increase. A study by McDonald and Schroder (2003) found that the feeder cattle purchase price had the biggest impact on profit per head of cattle sold on a grid,

followed by base price of the gird and cost of gain, respectfully. Individual premiums and discounts associated with quality had more of an impact on profit per head than premiums and discounts associated with yield.

Revenue variability per head increases from live weight to dressed weight, dressed weight to dressed weight & grade, and from dressed weight & grade to grid pricing (Fausti, Feuz and Wagner, 1998). Fausti, Feuz and Wagner (1998) found that in a pen where only 42% of the cattle graded choice or higher, dressed weight pricing yielded a higher revenue than that of grid pricing with a lower variation. This study then looked at a pen of above and below average cattle and found that revenue increased in the above average pen and decreased in the below average pen under grid pricing relative to dressed weight pricing. Revenue variation increased using grid pricing over dressed weight pricing in both pens. Schroeder and Graff (1999) found that the highest average revenue occurred when cattle were sold using dressed weight pricing, follow by grid pricing and live weight pricing, respectfully. Revenue variability increased moving from live weight to dressed weigh to grid pricing. If the individual animals were allowed to be sold on the highest pricing system, 52% would be sold using grid pricing, 46% would use dressed weight pricing and 2% would use live weight pricing. If these cattle were sold under the highest price method, the average price would increase by \$34.74 per head over selling all the animals under live weight pricing, \$15.14 per head increase over dressed weight pricing, and \$18.67 per head over grid pricing. Higher quality cattle received a higher price if sold on a grid and the lower quality cattle received a higher price if sold on a live weight basis. Anderson and Zeuli (2001)

simulated a set of cattle data to determine the price and risk change through various cattle marketing methods. When evaluating the entire data set, the pens of cattle sold on a grid received a higher revenue than is sold using live weight pricing, regardless of the quality of the pen. The results also showed that revenue variability is greater in grid pricing, regardless of pen quality, with the largest revenue variability appearing in lower quality pens of cattle. Fausti and Qasmi (2002) compared selling above and below average pens on a grid to selling them under dressed weight pricing and found that revenue was higher using grid pricing for the above average pen of cattle. Below average pens of cattle earned higher revenue if sold using dressed weight pricing. Revenue variability increased with grid pricing relative to dressed weight pricing regardless of cattle quality. Overall, the marketing method that yields the highest revenue depends on the quality of the cattle. Higher quality cattle have been found to receive a higher revenue if sold on a grid and lower quality cattle have been found to receive a higher revenue if sold by their live weight. Regardless of cattle quality, revenue variability is highest in grid pricing.

As the revenue variability increases from live to dressed to value based marketing methods, so does the price risk to the seller, or the feedlot, while price risk decreases for the buyer, or packers. From the buyers' perspective, live weight marketing is the most risky since the buyer must estimate the dressed percentage, quality and yield of an animal (Feuz, Fausti and Wagner, 1995). Dressed weight marketing is less risky for the buyer relative to live weight since the dressing percentage is known. There is even less risk for the buyer in value based marketing because the dressing percentage,

quality, and yield is known. Risk premiums are added for riskier investments and Feuz, Fausti and Wagner (1995) estimated these risk premiums. From the buyers' perspective, the risk premium for live weight over value based marketing was \$6.22 per head, \$2.55 per head premium for dressed weight over value based, and \$3.67 per head premium for live weight over dressed weight. Their results indicated that buyers perceive a higher risk when estimating dressing percentage over quality and yield. Pratt-Arrow risk aversion coefficients were calculated for packers and it was determined that, on average, packers are risk adverse. On the seller side, level of risk aversion varies from producer to producer, explaining the different marketing types.

Fausti and Qasmi (1999) conducted a study that looked at fluctuations within the premiums and discounts. They found that the cash market does not affect premium or discount prices. The study also found that many of the premiums and discounts seldom changed from one week to the next, and only fluctuates when the true values are seriously out of line with price values. Discount trends are found to be increasing and premium trends are found to be decreasing.

Literature Review Summary

Grade B maturity became a major focal point for the United States beef industry following the emergence of BSE in Washington state. BSE is a neurological disease in cattle that is formed from a TSE agent and infects the nervous system of cattle. The incubation period for this disease is typically four to six years but ranges from 20 months to 22 years (World Organization for Animal Health, 2010). Due to the long incubation

period, cattle under the age of thirty months are considered to be at negligible risk of contracting BSE.

BSE is spread by cattle consuming meat and bone meal derived from ruminant based animals that were infected with BSE. This led to the BSE epidemic in the United Kingdom where it was common practice to manufacture meat and bone meal derived from ruminant based animals to be utilized as a source of protein for cattle. The first confirmed case of BSE was in the United Kingdom in 1986, marking the beginning of the epidemic.

Sheep, deer, humans, and other mammals can be affected by other types of neurological diseases formed from TSEs. In humans, the common TSE based disease is CJD. In 1996, a variant of CJD, vCJD, emerged in humans. It was later proven that this new form of CJD was caused by the consumption of BSE contaminated material. This means that BSE could now be passed from cattle to humans, heightening the fear surrounding BSE.

US beef trade became drastically disrupted in December of 2003. Following the announcement of a confirmed case of BSE in the United States, the four countries that accounted for over 90% of the US beef exports closed their borders to US beef. These four countries would begin to reopen these markets in time, but placed age restrictions. These age restrictions revolved around the thirty months of age mark since cattle under that age were at negligible risk for BSE. The over thirty month discount would emerge in grid pricing shortly after the discovery of BSE in the United States.

USDA classifies cattle carcasses by their sex, maturity, quality and yield. Cattle can be classified as a steer (male), bullock (male), bull (male), heifer (female), or cow (female). There are five maturity classes recognized by the USDA, A through E. Grade A maturity carcasses are from cattle that were 9-30 months old at the time of slaughter, grade B maturity are cattle between 30-48 months old, and as cattle age beyond grade B, their maturity grades increase from C to E. As cattle age, their meat becomes tougher and redder which are undesirable traits, and as cattle age from grade A to grade B maturity, more marbling is required to achieve the same quality grade.

The USDA identifies eight quality grades, but grade A and B maturity cattle are the only cattle eligible to receive a quality grade of Prime, Choice, Select or Standard. Quality grades identify the palatability of the beef and is based off of the marbling and maturity of a carcass. There are five yield grades set forth by the USDA, yield grades 1 through 5. Yield grades are based upon several factors and calculates the boniness and meat yield that can be expected from a carcass. Both quality grades and yield grades are used in grid pricing.

Grid pricing is an alternative form of marketing cattle that uses premiums and discounts based on the carcass characteristics. This method is designed to send signals back to the producer to improve cattle quality. Many studies have been conducted comparing grid pricing and other value based marketing methods to the average pricing methods of live weight and dressed weight pricing. These studies show that revenue variability increases with grid pricing as compared to average pricing, higher quality cattle receive a higher revenue if sold on a grid, lower quality cattle receive a higher

revenue if sold using average pricing, and that risk to buyer decreases using grid pricing relative to average pricing. It was found that individual premium and discount prices have relatively little change from week to week and only really change when the value of the animal is out of line with the price of the premium or discount.

The over thirty month discount is a discount found in grid pricing. This discount emerged after the US beef trade disruptions due to BSE. This discount is a result of the lower quality of meat yielded from older cattle and the beef trade patterns between the United States and countries with age restrictions on beef. Little to none of the previous research in this area has examined the economic reasons for, or the factors that affect, the discount value.

CHAPTER III

METHODOLOGY

For this research, the absolute discount and the relative discount for cattle over the age of thirty months are considered separate from other values associated with a grid pricing system, such as the other premiums and discounts and the base price. The factors that affect the discount and relative discount are external variables including exports, prices, and supplies. By viewing the over thirty month discount as a price separate from other premiums and discounts and the base price, we see how these external factors directly affect the over thirty month discount and relative discount. This chapter will first take a theoretical approach to this research, followed by the development of the empirical model to be used for testing the hypothesis. The description of the data will conclude this chapter.

Theoretical Model

Economic theory states that as demand for a product falls (rises), prices will fall (rise). Export demand for US beef from cattle over the age thirty months fell drastically after the discovery of a BSE case in the United States. As a result of the decreased demand, the discount for these older cattle was created, dropping the price for those cattle. When countries such as Japan, South Korea, Mexico, and Canada began reopening their markets under age restrictions, the world demand for beef from younger cattle began to rise, as well as prices for this type of beef. This price increase signals to packers to produce more beef from cattle under thirty months of age. These re-established markets

are not importing beef from cattle over thirty months, resulting in the demand for this type of beef to remain constant. With the unchanged demand and limited slaughter capacity of a plant, packers demand less of these older cattle. Increased demand for beef in countries with age restrictions decreases the relative demand for beef from cattle over the age of thirty months and increases the discount.

Economic theory also indicates that as prices rise (fall), quantity demanded will fall (rise). If the overall price of cattle is increasing, then consumers will begin to purchase less beef or switch to a cheaper source of beef. Beef from cattle younger than thirty months is more likely to be processed into higher value cuts of meat due to its palatability. Beef from cattle older than thirty months may be more likely to be processed into lower value cuts of meat such as ground beef. This means that beef from cattle older than thirty months may be cheaper than from younger cattle. So as prices for cattle rise, consumers will demand more beef from cattle older than thirty months, increasing the value of these animals and decreasing the price of the discount.

The last bit of economic logic of the foundation for this research is that as supplies fall (rise), prices rise (fall). As the relative supply of cattle over the age of thirty months increases, the overall price of these cattle will decrease. This is accomplished through the increase in the price of the discount. As supplies of these older cattle increase, the discount for cattle over the age of thirty months will increase.

This research evaluates two questions, 1) how these economic factors affect the over thirty month discount directly and 2) how these economic factors affect the relative over thirty month discount. In the second model, the relative discount is the discount as

a percent of steer price, which allows the analysis of how is this discount changing while indirectly accounting for changes in the overall beef market, such as tight supplies or increase demand for cattle.

The theoretical model analyzing how economic factors affect the over thirty month discount price directly is:

$$(1) \quad \text{OTMWA}_t = f(\text{OTWMA}_{(t-1)}, \text{STPR}_t, \% \text{NS\&H}_t, \% \text{JAP\&KOREXP}_t, \\ \% \text{CANEXP}_t, \text{JAPMKT}_t, \text{KORMKT}_t, \text{Spring}, \text{Summer}, \text{Fall})$$

where: OTMWA_t = the weighted average price of the discount for cattle over thirty months of age in time t

$\text{OTWMA}_{(t-1)}$ = the dependent variable lagged by one time period (one week)

STPR_t = steer price in time t

$\% \text{NS\&H}_t$ = percentage of non-steers and heifers, used as the proxy for supply

$\% \text{JAP\&KOREXP}_t$ = percent of US beef exports to Japan and South Korea

$\% \text{CANEXP}_t$ = percent of US beef exports to Canada

JAPMKT_t = dummy variable for the reopening of the US-Japan beef trade

KORMKT_t = dummy variable for the reopening of the US-South Korea beef trade

Spring = Seasonal variable for the spring months of March, April, and May

Summer = Seasonal variable for the summer months of June, July, and August

Fall = Seasonal variable for the fall months of September, October, and

November

The second theoretical model, which analyzes the relative discount under the same economic factors, is:

$$(2) \quad \text{DSP}_t = f(\text{DSP}_{(t-1)}, \text{STPR}_t, \% \text{NS\&H}_t, \% \text{JAP\&KOREXP}_t, \% \text{CANEXP}_t, \text{JAPMKT}_t, \text{KORMKT}_t, \text{Spring}, \text{Summer}, \text{Fall})$$

where: DSP_t = discount as a percent of steer price

$\text{DSP}_{(t-1)}$ = the dependent variable lagged by one time period (one week)

*All other variables are defined above

Empirical Model

The empirical models are an expansion of the theoretical models described above.

Ordinary least squares regression methods are utilized when estimating the two empirical models.

The over thirty month discount is estimated as:

$$(3) \quad \text{OTMWA}_t = \beta_0 + \beta_1 \text{OTMWA}_{(t-1)} + \beta_2 \text{STPR}_t + \beta_3 \% \text{NS\&H}_t + \beta_4 \% \text{JAP\&KOREXP}_t + \beta_5 \% \text{CANEXP}_t + \beta_6 \text{JAPMKT}_t + \beta_7 \text{KORMKT}_t + \beta_8 \text{Spring} + \beta_9 \text{Summer} + \beta_{10} \text{Fall} + e$$

The relative discount is estimated as:

$$(4) \quad \text{DSP}_t = \beta_0 + \beta_1 \text{DSP}_{(t-1)} + \beta_2 \text{STPR}_t + \beta_3 \% \text{NS\&H}_t + \beta_4 \% \text{JAP\&KOREXP}_t + \beta_5 \% \text{CANEXP}_t + \beta_6 \text{JAPMKT}_t + \beta_7 \text{KORMKT}_t + \beta_8 \text{Spring} + \beta_9 \text{Summer} + \beta_{10} \text{Fall} + e$$

Several variables within the theoretical and empirical models are calculated.

Below are the calculations of these variables:

$$(5) \quad \text{DSP} = -(\text{OTMWA}/\text{STPR})$$

$$(6) \quad \%NS\&H = 1 - [(FIST - FIH) / FICAT]$$

$$(7) \quad \%JAP\&KOREXP = (JAP + KOR) / EXP$$

$$(8) \quad \%CANEXP = CAN / EXP$$

where: FIST = number of federally inspected steer carcasses

FIH = number of federally inspected heifer carcasses

FICAT = total number of federally inspected cattle carcasses

JAP = total metric tons of US beef exports to Japan

KOR = total metric tons of US beef exports to South Korea

CAN = total metric tons of US beef exports to Canada

EXP = total metric tons of US beef exports

The variable %NS&H is used as a proxy for supply. Typically fed steers and heifers will be younger than thirty months old when slaughtered. This variable is designed to capture the supplies of cattle not identified as steers or heifers, which have a higher probability of being older than thirty months, relative to the total supply.

The variables %JAP&KOREXP and %CANEXP are employed to represent the export demand for US beef in Japan and South Korea and the export demand for US beef in Canada relative to the amount of US beef exports. Since Japan and South Korea do not import US beef from cattle over the age of thirty months, these two countries are analyzed as one market for US beef. Canada is analyzed as a separate market since this country no longer maintains the age restrictions on US beef. By distinguishing between these two markets, the results show how trade regulations affect the over thirty month discount and relative discount.

By plugging equations (6), (7), and (8) into equations (3) and (4), the discount and relative discount for cattle over thirty months of age are affected by the lagged dependent variables, steer price, the number of federally inspected steers, heifers, and total cattle, and the volume of US beef exports and the amount exported to Japan, South Korea, and Canada.

With the time series nature of the data, the presence of autocorrelation is tested and corrected for. The models are run in SAS 9.4 using the PROC AUTOREG command to correct potential autocorrelation. This command uses the Yule-Walker method as the correction procedure. The Durbin h test statistic is utilized to ensure that potential autocorrelation problems are resolved.

Data Description

The data used for this study consists of weekly data of the over thirty month cattle discount price, steer price, amount of federally inspected cattle, and beef exports. All of the data used for this analysis was collected by the USDA-AMS, compiled by the Livestock Marketing Information Center (LMIC), and covers the January 26, 2004 to October 13, 2015 time period.

Over this time, the over thirty month cattle discount grew from \$9.60/cwt to \$16.42/cwt, and the relative discount increased from 8% in 2004 to 18% by 2010, then decreased to 10% by 2014. Figure 6 shows the changes in these values over time. The over thirty month discount is the weighted average of the price of the discount from Texas, Oklahoma, New Mexico, Kansas, Nebraska, Colorado, Iowa and Minnesota

packers. The steer price is the weighted average steer prices negotiated on a live FOB basis for Texas, Oklahoma and New Mexico.



Figure 6: Over Thirty Month Discount and Relative Discount Changes

The percentage of non-steer and heifers slaughtered is the percentage of federally inspected cattle that were not identified as steers or heifers. The method of calculating this variable, described above, is designed to provide a relative value of the supply of cattle older than thirty months. These percentages range from 14% to 26% with a strong seasonality component, but overall the percentages are not trending up or down.

On any given week in 2015, Japan and South Korea combined accounted for 38% to 61% of the total weekly US beef exports. This, coupled with Japan and South Korea’s age restrictions on the beef imported from the US, causes these countries’

demand for US beef to be an influencing factor on the over thirty month discount. The percentage of US beef exports to Japan and South Korea increased steadily over the time period from 0% in 2004 to 50% in 2014 and 40% in 2015. This variable is a proxy for the demand for US beef in Japan and South Korea.

Canada accounted for 5% to 13% of the total weekly US beef exports in 2015. As with Japan and South Korea, the volume exported to Canada is hypothesized to affect the over thirty month discount. US beef exports to Canada have ranged from 9% to 16% of total exports over the 2004 to 2015 time period. Figure 7 shows the relationship between the percentage of US beef exports to Japan and South Korea to the percentage of exports to Canada.

Weekly US beef exports increased from 154 metric tons of beef in 2004 to 19,400 metric tons in 2011, and decreased to 11,700 metric tons in 2015. Average weekly US beef exports to Japan increased from zero exports in 2004 to 3,394 metric tons in 2015 and exports to South Korea increased from zero in 2004 to 1,823 metric tons in 2015. Average weekly exports to Canada varied from 220 metric tons to 2,046 metric tons over the time period.

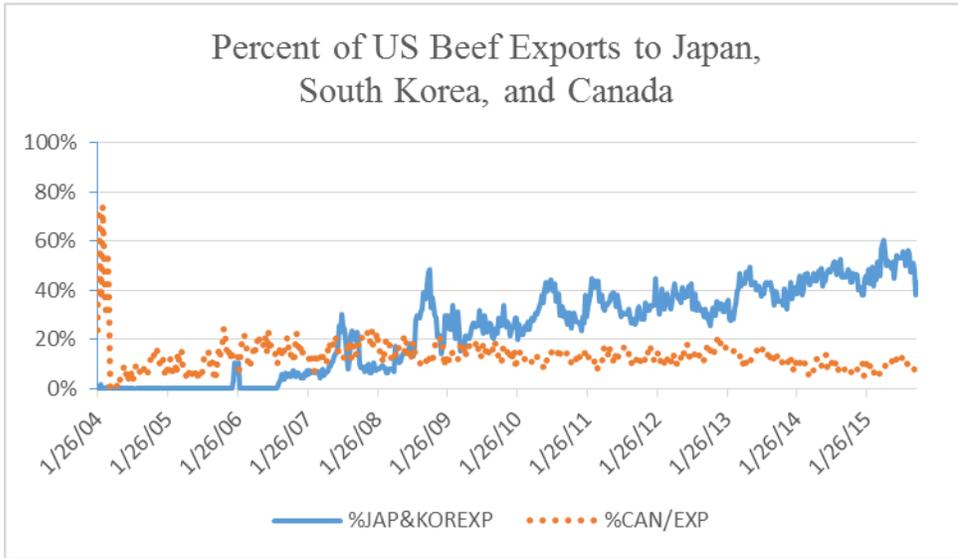


Figure 7: Percent of US Beef Exports to Japan, South Korea, and Canada

CHAPTER IV

RESULTS

This chapter begins by displaying the descriptive statistics and correlation matrix of the data and discusses how both are used to develop the model. Following this information, the results of both the discount and relative discount models are displayed. The chapter is concluded with an interpretation of the results for both models.

Data Results

The summary statistics of the data on the discount, relative discount, steer price, percent of non-steers and heifers, percentage of US beef exports to Japan and South Korea, percentage of US beef exports to Canada, and the dummy variables for the reopening of the four markets are displayed in Table 1. High correlation between variables used in the model and variables not included in the model occur due to the time series nature of the data. Table 2 shows the full correlation matrix.

Originally, the model was set to incorporate the percentage of US beef exports to Mexico by combining this value with the exports to Canada in the same manner that exports to Japan and South Korean were combined. The high correlation between the percentage of exports to Japan and South Korea and the percentage of exports to Mexico and Canada warranted a reworking of the model. The model was adjusted by dropping exports to Mexico. The percentage of exports to Canada then became the variable used in the model.

Table 1: Data Summary Statistics for Over Thirty Month Old Cattle Discount and Trade

	Mean	Min	Max	St. Dev.
Over 30 Month Discount	-12.97/cwt	-16.63/cwt	-6.42/cwt	3.184
Discount as a % of Steer Price	12.22%	7.52%	17.99%	0.0250
Steer Price	107.07/cwt	74.92/cwt	172.00/cwt	24.823
% of FI Non-Steers and Heifers	19.68%	13.94%	25.60%	0.0227
% of exports to Japan and Korea	23.99%	0.00%	60.31%	0.174
% of exports to Canada	13.33%	0.00%	74.02%	0.0624

Two additional variables were removed from the original hypothesized model. These variables were the dummy variables for the reopening of the US-Mexico beef trade and the US-Canada beef trade. These variables produced a mean of 0.99 for Mexico and a mean of 1.0 for Canada. The means being, or so close to, one indicates that there is little to no variability within these variables. Therefore, these variables will provide little to no explanation for the changes in the discount and relative discount.

Table 2: Full Correlation Matrix of the Variables

	STPR	%NS&H	%J&K/EXP	%M&C/EXP	%CAN/EXP	%MEX/EXP	JAPMKT	KMKT	MEXMKT
STPR	1.00	0.36618 <.0001	0.79261 <.0001	-0.75436 <.0001	-0.26905 <.0001	-0.68276 <.0001	0.43166 <.0001	0.49025 <.0001	0.10226 0.0114
%NS&H	0.36618 <.0001	1.00000	0.54783 <.0001	-0.63714 <.0001	0.04425 0.2744	-0.64024 <.0001	0.62651 <.0001	0.59493 <.0001	0.05819 0.1505
%J&K/EXP	0.79261 <.0001	0.54783 <.0001	1.00000	-0.94169 <.0001	-0.19422 <.0001	-0.88548 <.0001	0.69202 <.0001	0.77523 <.0001	0.12379 0.0022
%M&C/EXP	-0.75436 <.0001	-0.63714 <.0001	-0.94169 <.0001	1.00000	0.06949 0.0858	0.97234 <.0001	-0.70778 <.0001	-0.77472 <.0001	-0.00712 0.8605
%CAN/EXP	-0.26905 <.0001	0.04425 0.2744	-0.19422 <.0001	0.06949 0.0858	1.00000	-0.16545 <.0001	0.01891 0.6405	-0.05842 0.1489	-0.61401 <.0001
%MEX/EXP	-0.68276 <.0001	-0.64024 <.0001	-0.88548 <.0001	0.97234 <.0001	-0.16545 <.0001	1.00000	-0.70414 <.0001	-0.75221 <.0001	0.13673 0.0007
JAPMKT	0.43166 <.0001	0.62651 <.0001	0.69202 <.0001	-0.70778 <.0001	0.01891 0.6405	-0.70414 <.0001	1.00000	0.82549 <.0001	0.18096 <.0001
KMKT	0.49025 <.0001	0.59493 <.0001	0.77523 <.0001	-0.77472 <.0001	-0.05842 0.1489	-0.75221 <.0001	0.82549 <.0001	1.00000	0.14938 0.0002
MEXMKT	0.10226 0.0114	0.05819 0.1505	0.12379 0.0022	-0.00712 0.8605	-0.61401 <.0001	0.13673 0.0007	0.18096 <.0001	0.14938 0.0002	1.00000

where: %M&C/EXP = percent of US beef exports to Mexico and Canada

%MEX/EXP = percent of US beef exports to Mexico

MEXMKT = dummy variable for the reopening of the US-Mexico beef trade

*All other variables are defined above

Table 3: Regression Results Explaining the Over Thirty Month Cattle Discount

	Over Thirty Month Discount		Relative Over Thirty Month Discount	
	Value	Probability	Value	Probability
R ²	0.9888		0.9655	
Durbin h Test Statistic	-2.3826	0.0086	-0.7495	0.2269
Variable	Coefficient	P-Value	Coefficient	P-Value
Intercept	-0.0619	0.7824	0.0132	0.0004
OTMWA _(t-1)	0.9456	<0.0001	N/A	N/A
DSP _(t-1)	N/A	N/A	0.9095	<0.0001
STPR	-0.000669	0.5070	-0.000114	<0.0001
%NS&H	-2.4753	0.0212	0.0407	0.0040
%JAP&KOREXP	-0.3149	0.2074	0.0111	0.0008
%CANEXP	0.6745	0.0045	-0.0104	0.0012
JAPMKT	-0.0176	0.7869	-0.000127	0.8849
KMKT	-0.1335	0.0456	0.001336	0.1385
Spring	-0.007541	0.8597	0.0000859	0.8814
Summer	-0.0367	0.4610	0.000481	0.4735
Fall	0.0541	0.1785	-0.000784	0.1501

Results of Both Models

The results of the regression models estimated in equations (3) and (4) are contained in Table 3. The Over Thirty Month Discount model, equation (3), produced an R^2 of 0.9888 and the Relative Over Thirty Month Discount model, equation (4), produced an R^2 of 0.9655. These results indicate that 98.88% of the variation in the price of the discount and 96.55% of the variation in the relative price of the discount are explained by their respective models.

The Durbin h test produced a value of -2.3826 and -0.7495 for the discount and relative discount models respectively. This test follows a standard normal distribution which sets the critical values of -1.96 and 1.96 at the 95% confidence level. If the Durbin h test statistic is between the values stated, then the test fails to reject the null hypothesis of no autocorrelation. This means that the Durbin h test rejects the null hypothesis of no autocorrelation in the discount model, but fails to reject the null hypothesis of no autocorrelation in the relative discount model. This indicates that some autocorrelation may still be present in the discount model, but not in the relative discount model.

Within the Over Thirty Month Discount model, the lagged dependent variable, percentage of non-steer and heifers slaughtered, Canadian percentage of total US beef exports, and the dummy variable capturing the resumption of beef trade between the United States and South Korea are statistically different from zero at the 95% confidence level. The remaining variables, steer price, percentage of exports to Japan and South Korea, dummy variable for the resumption of United States trade with Japan, and the

seasonality variables are not statistically significant. Within the Relative Over Thirty Month Discount model, the lagged dependent variable, steer price, percentage of non-steer and heifers, percentage of exports to Japan and South Korea, and percentage of exports to Canada are statistically different from zero at the 95% confidence level. The dummy variable for beef trade resumption between the United States and Japan, and between the United States and South Korea, and the seasonality variables are not statistically significant.

Over Thirty Month Discount Interpretation

This model analyzes the price of the discount directly and since this is a discount, the dependent values of the model are negative. This in turn means that the discount grows when the price becomes more negative. The opposite is that the discount shrinks if the price becomes less negative. This is a crucial factor in the analysis of the results.

The coefficient value for the lagged dependent variable is 0.9456. This value being relatively close to one indicates that there is often very little to no variation in the discount from week to week. The discount values contained in Figure 6 support the close to one value. In Figure 6, the discount makes several large jumps in the beginning of the data series, but often holds steady for a period of time before making these jumps. In the latter part of the data, a steady increase in the discount is seen, although the changes in the discount possess minute fluctuations from week to week.

Steer price produced a coefficient value of -0.000669. Although it is statistically not different from zero, this variable is still discussed in order to juxtapose the two models later. The interpretation of this variable is if steer price rises, then the discount

becomes more negative, or grows. This indicates that as cattle prices increase, cattle over the age of thirty months are less demanded, and therefore, receive a higher discount. These results are different than those hypothesized in the Methodology chapter that concluded if beef and cattle prices rise, consumers will demand more of the lower quality beef produced from cattle over thirty months as a substitute for the higher quality and more expensive beef produced from cattle younger than thirty months. It would also be expected that meat packers, during tight supplies, would need these cattle and decrease the discount. Again, this value is not statistically significant at the 95% or 90% confidence levels.

The proxy for supply variable, %NS&H, yielded a coefficient value of -2.4753. The negative nature of this value means that as this percentage increases, the discount become more negative, or grows. If this percentage were to increase by one, the model estimates that the discount would grow by \$2.48/cwt. This variable has the largest coefficient value of all the variables in the model. The negativity of this coefficient value conforms to the economic theory that an increase in supply will decrease price.

The percentage of US beef exports to Japan and South Korea has a coefficient value of -0.3149, although it is not statistically significant. This indicates that as the relative demand for beef in these countries increase, the discount will grow. This market represents countries that do not import US beef from cattle over thirty months of age. So as countries with age restrictions demand a larger share of the total US beef exports, the discount will increase. The sign of this variable meets coincides with the hypothesis

stated in the Methodology chapter. A priori hypothesis was that the percentage of beef exports to Japan and South Korea would have been a more important variable.

The coefficient value for the percentage of US beef exports to Canada is equal to 0.6745. As the relative exports of beef to Canada increases, the discount will become less negative, or will shrink. If US beef exports to Canada increased by one percent, the discount would shrink by \$0.6745. This implies that countries without age restrictions may be important destinations for US beef and as their share of exports rises, the discount shrinks to the benefit of the US beef industry. The overall rise in the discount is due in part to the reduced relative demand from countries without age restrictions and an increased relative demand from countries with age restrictions. Visual inspection of Figure 7 shows that the percentage of US beef export to Japan and South Korea are rising. The increase in exports to Asia acts to increase the discount and results in reducing the percentage of US beef exports to Canada, also increasing the discount.

The resumption of US beef exports to Japan and South Korea are modeled within dummy variables, which yielded coefficient values of -0.0176 and -0.1335 respectively. The variable for Japan is not statistically significant, but reopening the South Korean market is significant. Since both of these values are negative, the model estimates that when the markets opened in these two countries the discount became more negative, or grew. These countries reopened their markets under age restrictions, making the demand for beef from younger cattle grow. This in turn increases the relative demand for this younger beef and reduces the relative demand for older beef, increasing the discount.

Relative Over Thirty Month Discount Interpretation

This model analyzes the relative discount which is percentage form. Unlike the discount analyzed in the previous section, these percentages are positive, as can be seen in equation (5). This in turn means that the relative discount grows as the percentage grows. The opposite is that the discount shrinks as the percentage becomes lower.

The coefficient for the lagged dependent variable is 0.9095. As with the discount model, the coefficient value is relatively close to one, indicating little to no variation in the relative discount from week to week. Although, this value is less than the coefficient value for the discount model, indicating that there is greater fluctuations from week to week in the relative discount. Figure 6 shows this relationship between the discount and relative discount.

The steer price variable produced a coefficient estimate of -0.000114. This model estimates that if steer prices were to increase by one dollar per hundred weight, the relative discount would drop by 0.0114%. A rise in steer price translates into higher prices to the packers for younger cattle. As a result, packers will demand less of this type of cattle and more of the cheaper older cattle. This in turn decrease the relative discount and increases the relative price of the older cattle, making older cattle more valuable.

The proxy for supply variable yielded a coefficient value of 0.0407. This means that as the relative supply of these older cattle rise, the relative discount will rise. The model estimates that if the percentage of non-steer and heifers rise by one percent then the relative discount will rise by 4.07%. This coincides with the a priori hypothesis that

if supplies rise, the prices will fall, or in this case the discount rises. Other than the lagged dependent variable, the proxy for supply yields the highest coefficient within this model.

The coefficient for the percentage of exports to Japan and South Korea is positive at 0.0111. If the percentage of exports to Japan and South Korea increase by one, then the model estimates that the relative discount will increase by 1.11%. Therefore, as a higher percent of US beef exports go to countries with age restrictions, the relative discount will increase. The sign of the coefficient for this variable coincides with the hypothesis stated in the Methodology chapter.

The coefficient for the percentage of exports to Canada is negative at -0.0104. If the percentage of exports to Canada increases by one, then the model estimates that the relative discount will decrease by 1.04%. This yields the opposite effect to that of exporting a higher percentage of US beef to Japan and South Korea. As a result, if a higher percentage of US beef is exported to countries without age restrictions, it is expected that the relative discount will decrease, and these older cattle become more valuable.

Then next two variables, the dummy variables for the reopening of the US beef trade with Japan and with South Korea produced coefficient values of -0.000127 and 0.001336, respectfully. Neither of these variables are statistically different from zero. However, the value of these coefficients indicate that when Japan reopened their market, the relative discount fell, while when South Korea reopened their market, the relative discount rose.

Comparison of the Two Models

Several interesting facts emerge when comparing the results of the two models side by side. The first is that the dummy variable for the reopening of the Japan market is the only variable, other than seasonality, that is statistically insignificant in both models. All of the other variables are significant in at least one of the models. Secondly, the proxy for supply has the largest impact on both the discount and the relative discount. This variable alone impacts the discount and relative discount more than the percentage of exports to Japan and South Korea and the percentage of exports to Canada combined.

The last important aspect to recognize is that the economic factors influence the discount and relative discount the same direction for all of the variables except for steer price and the reopening of the Japan market. If the proxy for supply or percentage of exports to Japan and South Korea increases, then both the discount and relative discount will increase, whereas if the percentage of exports to Canada increases then the discount and relative discount will decrease. For both models, the reopening of the South Korean market increased the discount and relative discount. This occurs for these four variables regardless of significance.

CHAPTER V

CONCLUSIONS

Following the emergence of Bovine Spongiform Encephalopathy in the United States, countries that imported US beef placed bans and restrictions on this trade. These restrictions revolved around an age requirement. The four major importing countries of US beef, at some point in time, would only import beef from cattle younger than thirty months of age. A close review of the literature found that cattle under thirty months of age are at negligible risk for obtaining BSE and beef from cattle older than thirty months is not as palatable as that of beef from younger cattle. The result is the formation of a discount in grid pricing for cattle over the age of thirty months.

This research analyzed the impacts that economic factors have upon the over thirty month discount and the relative over thirty month discount. The fluctuations in the discount and relative discount are shown to be caused by beef exports, export regulations, cattle prices, and supplies.

These impacts are analyzed with time series modeling using the ordinary least squares regression method. The models are corrected for autocorrelation through an imbedded program in SAS 9.4. Relative variables are utilized to demonstrate the effects that economic factors have on the discount and relative discount without being overshadowed by other changing market conditions, such as growing total exports.

The results of the models show that steer price, supplies, relative exports, and export restrictions all impact either the discount, relative discount, or both. Supplies has

the greatest impact on the discount and relative discount followed by the relative exports to the two types of markets. In both models, increase in supplies increase the discount and relative discount, making these cattle less valuable. An increase in the percentage of exports to countries that still maintain age restrictions on US beef will increase the discount and relative discount. On the other side, an increase in the percentage of exports to countries without age restrictions will decrease the discount and relative discount. This translates to cattle over the age of thirty months becoming less valuable as a larger percent of beef exports goes to countries with age restrictions, and more valuable as a higher percentage goes to countries without age restrictions.

Ever since the emergence of BSE and the bans on US beef were put into place, the United States has been working with countries to eliminate the bans and reduce the restrictions. This research provides some insight on how the value of cattle over the age of thirty months changes as different economic factors change. If the United States continues to see export restrictions on its beef reduced, then we will see the discount decrease and the value and demand of cattle over thirty months of age increase. As this occurs, packers could see larger quantities of older cattle being slaughtered and feeders may begin to see higher revenue for these cattle. This could possibly trickle down to the cow/calf producer, allowing higher overall revenue within their operation.

This research focused primarily on relative exports and export restrictions on US beef from cattle over thirty months of age. In all, this research ignored the potential cost of processing these older cattle. These cost could include special equipment for handling older, larger animals, or the cost associated with keeping the meat separate

from beef from cattle under thirty months old. Future advancement on this topic should look to incorporate these added costs for the cattle over thirty months of age.

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