IMPACT OF INCREASING BRAZILIAN CATTLE PRODUCTION EFFICIENCY ON BRAZILIAN BEEF PRODUCTION

A Thesis

by

ANDREA MCKENZIE GURNEY

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Chair of Committee,	Luis Ribera
Committee Members,	David Anderson
	David Riley
Head of Department,	Mark Waller

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ABSTRACT

As the world population grows and the demand for meat increases, pressure is placed on the agricultural industry to satisfy societal needs. Having the largest commercial cattle herd, and 50% lower production costs than the United States, Brazil may be able to meet future societal needs and demands through increases in Brazilian cattle production efficiency. From 1990 to 2017 Brazil went from producing 24.45 kg of live weight/ha/year to 60.15 kg of live weight/ha/year. Brazil has the opportunity to realize larger productivity increases by improving carcass weights and weaning percentages. The current average Brazilian carcass weight is 547.22 lbs. and the weaning percentage is 31.6% compared to a U.S. average carcass weight of 819 lbs. and an 83.5% weaning percentage in certain regions of the U.S.

The objective of the current study was to determine how varying levels of cattle production efficiency in carcass weights and weaning percentages would impact Brazilian beef production in the next 50 years. Structural and trend models were used to project Brazilian carcass weights and weaning percentages out 50 years. Different scenarios were analyzed to determine how different levels of carcass weights and weaning percentages would impact beef production. A structural model forecasted Brazilian carcass weights and weaning percentages to be 707 lbs. and 56.77% by 2068 respectively, resulting in an increase of production by 137%. If Brazil achieved U.S. carcass weight and weaning percentage levels by 2068, beef production would increase by 308%. The results of the current study may be further utilized to analyze the effects that an increase in Brazilian beef production would have on the U.S Beef Industry.

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CHAPTER I

INTRODUCTION

Brazil has a significant presence in global beef markets as the largest global beef exporter in 2018 and that presence will likely continue to expand (USDA, Foreign Agricultural Services 2018; Appendix A-1). Brazil's competitive strength has improved by producing meat more efficiently through increased productivity. From 1990 to 2017 Brazil went from producing 24.45 kg of live weight/ha/year to 60.15 kg of live weight/ha/year, resulting in a productivity increase of 146% (Brazil, Brazilian Beef Exporters Association 2018). Brazil was also able to reduce the area occupied by cattle by 235 million hectares (Brazil, Brazilian Beef Exporters Association 2018; Appendix A-2). In 2018 Brazil has produced 9.9 million metric tons carcass weight equivalent (MMT CWE) of beef, of which 2.03 MMT CWE contributed to beef exports allowing Brazil to surpass India as the largest global beef exporter (USDA, Foreign Agricultural Services 2018; Appendix A-1). Brazilian beef production has increased by 51.8% since 2000 when production was 6.5 MMT CWE, and there is reason to believe that this growth may continue, due to increased global demand as the world population increases (USDA, Foreign Agricultural Services 2018).

The world's population is expected to exceed ten billion people by the year 2050 (Rekacewicz 2005; Appendix A-3.). Coupled with an expected increase in world gross domestic product (GDP) (European Union, European Environment Agency 2017; Appendix A-4) the demand for protein consumption is projected to increase as well. In developed countries, per capita meat consumption is expected to grow 14% between now and the year 2050 (Alexandratos and Bruinsma 2012). In the same time frame, world aggregate demand for meat is expected to grow by 1.7% per annum from now to the year 2030. (Alexandratos and Bruinsma 2012). The current world aggregate demand growth rate for meat is one half of the comparable historical period when the growth rate was 2.9% in the preceding 30 years. (Alexandratos and Bruinsma 2012). Despite lower world aggregate demand growth rates for meat, to meet the anticipated demand, beef supply would have to increase. Having the largest commercial cattle herd, and 50% lower production costs than the United States, Brazil may be able to satisfy the increase in demand (Somwaru and Valdes 2004). However, to achieve necessary supply levels, efficiency of Brazilian cattle production would need to increase.

Should new technologies and management practices be adopted, Brazil will potentially find themselves as a bigger competitor in international markets. While studies have been conducted on Brazilian beef production, there is little research evaluating different levels of potential future production. The objective of the current study is to bridge the gap by determining how varying levels of cattle production efficiency would impact Brazilian beef production over the next 50 years. The results of the current study may be further utilized to analyze the effects that an increase in Brazilian beef production would have on the U.S Beef Industry. As the largest global beef exporter, understanding Brazil’s future competitive strength becomes imperative (USDA, Foreign Agricultural Services 2018; Appendix A-1).

CHAPTER II

REVIEW OF LITERATURE

Background

Brazil is a large player in the global grain industry, as the second largest producer of soybeans and corn (behind the U.S.) with production totaling 119.5 MMT and 82 MMT respectively in 2017 (USDA, Foreign Agricultural Services 2018). Brazil has tripled their soybean production from 39.5 MMT in 2000 to 119.5 MMT in 2017. In addition, Brazil's average yields are 3.41 metric tons per hectare (MT/HA), up from 2.84 MT/HA in 2000 and the yields are continuing an upward trend (USDA, Foreign Agricultural Services 2018; Adcock et al. 2017). While soybean yields are contributing to the increase in total production, numbers of hectares harvested are increasing as well. In the year 2000, approximately 13.9 million hectares were harvested, while in 2017 harvested hectares increased to 35.1 million hectares (USDA, Foreign Agricultural Services 2018). Since 2012 Brazil has surpassed the United States as the largest exporter of soybeans, with current exports totaling 76.7 MMT, 18.7 MMT greater than the United States (USDA, Foreign Agricultural Services 2018; A-5). Concurrently, U.S. production of soybeans was slightly greater than Brazil's in 2017, totaling 119.52 MMT. Soybeans were harvested from 35.96 million hectares (USDA, Foreign Agricultural Services 2018).

Brazilian corn production has increased from 41.5 MMT in 2000 to 82.0 MMT in 2017. During the same time frame, yields increased from 3.2 MT/HA to 5.4 MT/HA (USDA, Foreign Agricultural Services 2018). Brazil is the third largest exporter of corn behind the U.S. and Argentina. In 2017, world corn exports totaled 146 MMT, of which the U.S. accounted for 61.6

MMT, Argentina 23 MMT, and Brazil 22 MMT. In 2005, Brazilian corn exports were only 4.5 MMT while U.S. exports were 54.2 MMT (USDA, Foreign Agricultural Services 2018; A-6). Area harvested for Brazil remains considerably low compared to the U.S. at 16.6 million hectares vs. the U.S. with 33.5 million hectares harvested.

Increasing grain production could play a major role in influencing Brazilian beef production. Brazil has been the second largest beef producer behind the United States since 2005; Brazilian total beef production in 2018 has totaled 9.9 million metric tons carcass weight equivalent (MMT CWE), versus the U.S. production totaling 12.6 MMT CWE (USDA, Foreign Agricultural Services 2018). The vast majority of Brazilian cattle are *Bos indicus*, with the most common breed being Nelore (Figueiredo et al. 1997). The Nelore breed was first introduced in Brazil in 1868. Breeding contributions of the Nelore from purebred selection and crosses were significant. The Nelore offers distinguishing characteristics such as hardiness, heat and insect resistance, metabolic efficiency, meat quality, reproductive efficiency, and maternal instinct and disposition (Oklahoma State University Dept. of Animal Science 1997). The characteristics of the Nelore make the breed one of the best options for tropic regions, making the breed popular in Brazil. The utilization of the breed expanded the Brazilian herd from 56 million in 1965 to 160 million in 1995, of which 100 million are Nelore. The Nelore is also efficient at converting poor quality forages into beef, which is pertinent in Brazil as the vast majority of cattle are grass-fed.

In 2004, less than 3% of Brazil’s total beef production stemmed from cattle fed in confinement on grain-based diets (Somwaru and Valdes 2004). The number of cattle fed in confinement on grain-based diets increased to 13% of total cattle slaughtered in 2015, while the remainder of the cattle were grass-fed (Meat & Livestock Australia 2017). Brazil’s grass-fed production system allows them to produce a lean meat product at a low cost, but it requires a longer finishing time. Millen et al. (2011) explains that cattle are older at market if they were raised and fed solely on a grass system. Brazilian cattle average slaughter age is 36 months, whereas U.S. grain-fed cattle are harvested from 12-21 months of age (Thies 2012).

To achieve higher production levels sooner, a ruminant animal needs concentrate supplementation. The animal cannot ingest the energy requirements solely from forages to become high producing (Priolo, Micol, and Agabriel 2001). Therefore, grass-fed cattle take longer to finish and produce lighter carcasses. Capper (2012) analyzed different feeding systems in the U.S. and concluded that cattle in a grass-fed system finish in an average of 679 days of age while cattle in a grain fed (or conventional) system finish in an average of 444 days. The Beef Board (2007) agrees that it takes longer for grass-fed cattle to reach market weight than grain-fed in the United States. U.S. cattle in a conventional system also average 569 kilograms (kg) with an average dressing percentage of 63.8% at slaughter, while grass-fed cattle are reported to weigh 486 kg at slaughter with a 57.5% dressing percentage (Capper 2012). Analysis of different finishing scenarios in the United States reported that the average daily gain (ADG) associated with feedlot finishing was 1.4 kg while pasture finishing ADG was 0.6 kg (Pelletier, Pirog, and Rasmussen 2010).

As Brazil’s grain production continues to increase, Brazil should have the capability to capitalize on a cheap feed source that increases productivity. Not only could feeding grain reduce Brazil’s slaughter cattle’s finishing time, it may also contribute to increased production.

Capability for Increased Cattle Production Efficiency

As the demand for protein and world population grows, the adoption of new methods of production become necessary to satisfy the increase in demand. Having the largest beef cattle herd, Brazil has the opportunity to increase their production even further. While it may be believed that increased production can be accomplished through increased land use, this is no longer the case. Rather, Brazil has several options to increase their beef production through increased efficiency/productivity. Jank et al. (2014) conducted research analyzing how improved pasture management has contributed to Brazil's beef production. Such management has included forage breeding programs, and crop-livestock-forest systems. To assist in the formation of pastures, Brazil imported seeds of *Brachiaria decumbens* from Australia between the years 1968 and 1972. Brachiaria grass adapts easily to poor, acid soils and leads to better animal performance; resulting in Brachiaria grass being popular in the Brazilian Cerrados. The grass has reduced the amount of pasture needed per head from 2.56 ha/head in 1940 to less than 1.5 ha/head in 2006. Jank et al. (2014) concluded that Brazil has the capability to increase production to satisfy the growing demand for protein associated with the growing population by increasing the cattle herd to 227 million head. The research stated that increased production can be accomplished through increased efficiency rather than increased land use. In fact, meat production can be increased in Brazil while also reducing land use by 21.4 million hectares (Mha). The increase in meat production can be accomplished with higher quality pastures and dynamic breeding programs.

Lobato et al. (2014) agrees with the previous research. From 1950-1970, Brazilian beef production increased due to pasture expansion. However, from 1950-2006 there was a land-saving effect of 525 Mha due to productivity improvements explaining 79% of the growth in beef production. Increased production has relied on improving efficiency through adopting new technologies. Areas where productivity could be increased are through pregnancy and weaning rates/percentages. In many operations, pregnancy and weaning percentages are low. Currently the Brazilian average cow/calf ratio is roughly 56 calves for every 100 cows. Brazil will need to focus on improving ratios, such as cow/calf, to increase production in the future.

Martha, Alves, and Contini (2012), also supported the land-saving effect of beef production by determining whether land expansion or increased efficiency has contributed to increased beef production. Increased pasture area primarily contributed to increased beef production from 1950-1975. After 1985, animal performance contributed to 65-70% of the production growth. From 1996-2006 stocking rates contributed to 35% of the production growth.

Somwaru and Valdes (2004) analyzed Brazilian beef production's efficiency by using a non-parametric technique to measure its competitive strength and concluded that overall efficiency is low. This provides further confirmation that Brazilian beef production has room for improvement.

Factors of Production Growth

As Brazil focuses on increasing beef production, there are a plethora of areas that can thrive through increased efficiency ranging from carcass weights to weaning percentages. The key is to determine what areas may cause the most dramatic impact on Brazil's production. da Silva Neto and Bacchi (2014) focused on determining the factors that are contributing to Brazil's growth in beef production. From 1994 to 2009, heavier carcass weights contributed to the growth in meat production more than the number of animals slaughtered. A Vector Auto Regression model was used to determine the impacts of supply and demand shocks (an unexpected change) on livestock production and exports. The effect on production due to demand shocks is temporary, but permanent for supply shocks. Variables shocked included internal income, prices paid to the farmer and retail price, productivity, and total animal stock. Shocking animal stocks by +1% results in a decline in exports by 22%. The increase in animals stocks could be a result of future expectations for higher prices, leading to less cattle being slaughtered in the short run and less short run exports. In regards to the relation between beef production and animal stock, the matrix coefficient was negative, but not significant. Shocking productivity by +1% results in exports increasing by 1.2%. Animal stock and productivity had the larger effect on production. While initially animal stocks cause exports to decline by 22% in the first period, after the fifth quarter in the future, exports increase. da Silva Neto and Bacchi (2014) further explain that increases in animal stock and productivity have caused real production values to move closer to the forecasted figures.

Others agree that Brazil's production has increased due to a variety of factors over the years. According to McManus et al. (2016), during the 1990's productivity increased (weight kg/head/year) by approximately 30% while cattle growth was less at approximately 20%. In addition, there was a decline in the area used for beef production. Technological factors that have assisted in changing beef production in Brazil include increases in weaning rates and weights. From 2000-2010 weaning weights increased by 13.77% from 167 kg to 190 kg. First breeding ages also declined from 36 to 30 months. From 1960-2010 stockings rates progressed from 0.47 head/ha to 1.2 head/ha and the Brazilian cattle herd simultaneously increased by 251%. Other means to increase productivity in Brazil include pasture intensification. The purpose of pasture intensification is to not only free-up land for agricultural production, but also to reduce stress on forest margins (McManus et al. 2016).

According to de Camargo Barros, Spolador, and Bacchi (2009), over the past 40 years the evolution of Brazilian agricultural output has been explained by increases in productivity (yield increases); which has resulted in a moderate reduction of prices. In fact, output would rise by 4.8% in the long run and price would fall by 1.6% due to a 10% increase in yield, causing farm income to increase by 3.1%. Integration to international markets is also responsible for the continuous growth of agricultural output. Outside of yield, another factor considered that may influence output was growth in gross domestic product (GDP.) During the early 2000s, GDP was not significant in explaining agricultural output because the growth of the economy was inexpressive during that time. However, if Brazil had higher GDP growth rates there would be an expected increase in the demand of agricultural products. The increase in the demand of agricultural products leads to the opportunity for expansion within the agricultural sector. In addition, a 10% devaluation in the exchange rate causes agricultural output to increase by 3.7% in the long run. Brazil is anticipated to continue to increase agricultural output in foreign and domestic markets.

Carcass Weight & Weaning Percentage

Various areas of production have room for improved efficiency; however, the current study will simultaneously target carcass weights and weaning percentages. Considering beef production is a function of number of head and meat produced per animal (i.e. carcass weight), increases in carcass weights and weaning percentages should result in an increase of production.

Global production of livestock has dramatically increased from 23.6 MMT CWE in 1960 to 63.03 MMT CWE in 2018 (USDA, Foreign Agricultural Services 2018). The rise in livestock production is due to an increase in productivity and animal numbers (Thornton 2010). From 1960 to 2018 the global average carcass weight has increased by 23.1% from 457.19 lbs./head to 562.74 lbs./head (USDA, Foreign Agricultural Services 2018). Growth in carcass weight in developed countries will contribute more to increased production than animal numbers (Thornton 2010). In addition, more intensification of livestock production is expected.

According to Steinfeld, Wassenaar, and Jutzi (2006), intensification pulls from technical improvements, which include genetics and farm management. Technical factors can contribute to higher output per animal and resource-use efficiency. Offtake per unit of stock increased from 1980 to 2004 for pork and chicken by 61% and 32% respectively. Offtake rates in the future are going to play less of a role in beef production and more in pig and poultry production (Bruinsma ed. 2003). In addition, half of the world beef production is accounted for by developing regions. Bruinsma (ed. 2003) agrees with Thornton (2010) that increases in both animal numbers and productivity will increase production. Animal numbers will continue to increase, but at a decreasing rate. Instead, increased carcass weights will be a more significant component of beef production.

Carcass Weight

In order to analyze carcass weight as a factor of production it is necessary to understand carcass weights simultaneous relationships with other factors of production. Carcass weights are not only influenced by biological factors, but also by economic factors. Langemeier and Thompson (1967) concluded that simultaneous relationships exist within weight per head of fed beef slaughtered. Dressed weights per head of fed beef exhibited a positive relationship with fed beef farm prices, while corn prices had an inverse relationship with dressed weights per head.

In a study by Marsh (2007) similar relationships were considered. Cross-sector relationships were analyzed through a systems econometric model. Sectors evaluated included beef, pork, poultry (broiler), and corn. It was determined that cattle slaughter supply and slaughter steer price are positively related, but cattle slaughter supply and corn and feeder calf prices are inversely related (Marsh 2007). Similar results were reported within the slaughter hog sector as well. Slaughter hog price had a positive effect on hog supply, while corn price had a negative effect. Soybeans, a substitute of corn production, was analyzed as well. Corn production declines by 0.41% if soybean price increases by 1%. The purpose of recognizing the relationship between corn production and soybean price is to not disregard soybeans as a feed grain, particularly in Brazil. Brazil is the second largest soybean producer in the world, producing 119.5 MMT so focus must not only be placed on the corn sector as a feed source (USDA, Foreign Agricultural Services 2018).

Ospina and Shumway (1981) created a similar study to those done by Langemeier and Thompson (1967) and Marsh (2007); however, they took it a step further to analyze the U.S. livestock industry. Changes in corn prices were explained to not only impact the total supply of beef, but also the supply of various qualities of meat. If corn price increased by 10% there would be a 0.4% increase in lean (good and utility) beef supplies. There would also be a 4.8% decrease in choice beef supplies and an overall 2.4% reduction in total beef being marketed (Ospina and Shumway 1981).

Weaning Percentage

Weaning percentage (also referred to as percent calf crop) is a cow herd performance measure that can be impacted by numerous factors beginning with breeding. The formal calculation for weaning percentage is the number of calves divided by the number of females exposed to bulls (Reiling 2011). Exposed females is representative of the total number of females in the breeding herd, prior to adjustments being made. The exposed female number should not include females planned to be culled prior to breeding, and females exposed that are sold but are expected to calve. Females that are purchased and are expected to calve during calving window should be added to the calculation. If exposed females do not become pregnant, this negatively affects calving percentage and weaning percentage.

Calving percentage measures management and reproductive efficiency. When calving percentages are low, it may be an indicator of 1) inadequate nutrition, 2) poor adaptation relative to the environment, 3) lower fertility or bull power, or 4) the incidence of reproductive disease (Reiling 2011). In regards to bulls, the number of females and pasture size can affect the bull-to-cow ratio resulting in low pregnancy rates thus lowering calving percentage. Considering bull-to-cow ratios in management practices becomes important when aiming to increase weaning percentages. Reproductive diseases can also reduce pregnancy percentages, which simultaneously reduce calving and weaning percentages (Reiling 2011).

Another factor that influences weaning percentages is calf death loss. The calf death loss percentage can be affected by "…1) genetic selection, 2) the calving environment, 3) the herd health program, and/or 4) nutritional management" (Reiling 2011). Most death loss actually occurs after parturition, typically as a result of dystocia. Dystocia is primarily affected by high birth weights, so it becomes necessary to use proper genetic selection when selecting bulls for the herd. However, there is a low frequency of dystocia in Nelore cattle (Utsunomiya et al. 2013). One of the major issues associated with the Nelore breed is a reduction in calving rates of 20% from the first to the second conception (Mercadante, Lôbo, de Oliveira 2000). A combination of the aforementioned factors ultimately affects weaning percentages; which can make it difficult to analyze and gather data on weaning percentages alone.

Patterson et al. (1987) analyzed data collected from 13,296 calvings over 15 years in the U.S. Data indicated an average loss of 6.7% from birth to weaning. Death loss from birth through Day 3 postcalving accounted for over two-thirds of that loss, and the remainder of the loss came from calves dying from Day 4 through weaning. Dystocia was the most common cause of death loss in the first 96 hours postpartum. Other causes of death included health issues in the calves such as pneumonia and scours (Patterson et al. 1987). Wiltbank et al. (1961) concluded that conception failures and death losses shortly after birth are the largest contributors of losses in calf crop.

Clearly many factors affect weaning percentages from birth to weaning. Weaning percentages/percent calf crop become vital to producers and overall production. A larger calf crop is associated with increases in profit as a result of selling more calves (Brown 2016). The U.S. calf crop was higher by 3% in 2017 from 2016 and by 6% from 2015 (USDA, National Agricultural Statistics Service 2017). Larger slaughter cattle supplies may be expected for 2018 and 2019 as a result (Minter 2017).

Objective

Although research has been conducted to examine areas where Brazil has become more efficient in beef production and where efficiency can be improved, many gaps still exist. Additional research has analyzed cross-sector relationships amongst beef productivity factors and identified factors affecting weaning percentages. Brazilian beef production has also been projected to increase to 10.89 MMT by 2025 then reach 12.25 MMT by 2035. The projections represent a growth of 44% in 25 years that will be triggered by exports (Harfuch, Palauro, and Kimura 2016). However, no research has explained what variables will play a major role in increasing production. In particular, no research has examined how different levels in efficiency in both the cow-calf and finishing sector could lead to specific variations in total production over the next 50 years.

The current study evaluated how different levels of carcass weights and weaning percentages combined, could impact beef production in Brazil by year 2068. The levels of each variable represent varying intensities of efficiency in Brazilian cattle production. The purpose is to provide insight on how Brazilian beef production may look in 50 years.

CHAPTER III

DATA & METHODOLOGY

Initial Calculations

Production, Supply, and Distribution (PS&D) (USDA, Foreign Agricultural Services 2018) data were used to determine the annual average carcass weight and weaning percentage endogenous variables for Brazil. Average carcass weights were calculated by dividing total meat, beef, and veal production (in metric tons) by the total head of cattle slaughtered, then converted to pounds by multiplying by 2,204.62 lbs. (Metric Conversions 2018):

Carcass Weight/hd= (Total Hd. Slaughtered/ Beef Production (1000 MT CWE) *2204.62 lbs. ***(1)***

Carcass weight data ranged from 1960 to 2018.

Next, an implied weaning percentage (which ignores bulls) was calculated. Formally, weaning percentage is calculated by taking the number of calves weaned and dividing by the number of exposed females (Reiling 2011). However, there is no continuous data available to conduct a formal calculation. Brazil has a large commercial cattle herd where cattle are spread over thousands of acres of land, which could make it more difficult to collect weaning percentage data. Coupled with the fact that some ranchers may only see all of their cattle a limited number of times a year (due to the wide span of land) makes it more difficult to record such information. Which is why an implied calculation had to be developed as follows:

First, calf crop was estimated:

Calf Crop Estimation=Total Slaughter (Head)-Cow Slaughter (Head) **(2)**

The calf crop estimation does not decipher the age of the calves; therefore, there is a possibility for this data to be skewed. However, there is no continuous historical data on Brazilian calf crop so this approximation had to be developed. Next, dairy and beef cows were summed to receive a calculation for the total number of cows. Dairy cows were included because some dairy calves are harvested as well:

Total Number of Cows= Dairy Cows Beg. Stocks +Beef Cows Beg. Stocks **(3)**

The two former calculations were used to estimate an implied weaning percentage:

Implied Weaning Percentage= (Calf Crop Estimation/Total Number of Cow$_{T-1}$)*100 **(4)**

The implied weaning percentage was calculated by dividing the calf crop estimation by the total number of cows lagged by one period (T-1) then multiplied by 100. Total number of cows was lagged one period as last year's cows provide this year's calf crop. Due to beginning stocks data for dairy and beef cows being 0 until year 1974 weaning percentage data does not begin until 1975. Dairy and beef cow beginning stock numbers may not be available for earlier years because Brazil may not have had the means to record this information until later years.

Equations 1, 2, 3, & 4 served as the foundation for developing and analyzing three separate scenarios for Brazilian beef production.

Scenario 1

Scenario 1 applies the assumption that Brazilian carcass weights and weaning percentages remain constant at 2018's carcass weight and weaning percentage levels for the next

50 years. Therefore, Brazil does not change their current production practices or adopt new production technologies.

Scenario 2

Carcass weights and weaning percentages were forecasted using structural models to capture the effects that trend and other factors may have on weights and percentages. Simetar (Richardson, Schumann, and Feldman 2008) was used to forecast the average annual carcass weights and weaning percentages out 50 periods (years). To compose a structural model the cross-sector relationships of carcass weights were considered. Supply has been found to be a negative function of input prices and a positive function of the supply price (Marsh 2007). As a result, carcass weights are represented by the following function:

Carcass Weight= f (Maize Price, Soybean Price, Global Beef Price, Trend, Trend^2) ***(5)***

Carcass weight is a function of corn, soybean, and global beef price, trend, and trend^2. To estimate the parameters a multiple regression/OLS model was used. “OLS is preferred because it minimizes the sum of squared residuals” (Richardson 2018). Prior to running the structural model maize, soybean, and global beef prices were individually forecasted out 50 periods (years) as annual Brazilian projections are not currently available.

Secondary data for carcass weight exogenous variables was collected from the Food and Agriculture Organization of the United States (FAO of the United Nations 2018) and Federal Reserve Bank of St. Louis (Federal Reserve Bank of St. Louis 2016). Specifically, maize and soybean prices were collected from the FAO (FAO of the United Nations 2018). The maize and soybean prices represent Brazilian annual producer prices in USD/Tonne from 1991-2016. On the other hand, global beef price data was gathered from FRED, which provides data from 1980-

2016 (Federal Reserve Bank of St. Louis 2016). The global beef price should be relatively representative of Brazilian beef prices, as Brazil is a leading exporter of beef (USDA, Foreign Agricultural Services 2018). The FAO has annual producer prices for beef, but 4 years of data is missing (2007-2010). Although it is unclear why 4 years of data is missing, potential political issues could explain the inconsistency, considering political issues has influenced the Brazil Agricensus reports. The Brazilian Institute of Geography and Statistics (IBGE) offers an Agricultural Census; unfortunately, many years of data are missing and the reports are only conducted every 5 years. “The first Agricultural Census was carried out in the year 1920, as an integral part of the General Census. In the 1930s there was no Census due to political and institutional reasons. From 1940 the censuses were decennial until 1970. Subsequently, the periodicity changed to five years, realized in the beginning of years of end 1 and 6, and referred to years of end 0 and 5, that is, 1975, 1980 and 1985” (Brazilian Institute of Geography and Statistics 2017). At the completion of gathering data, each exogenous variable was forecasted individually:

$$\textit{Annual Producer Maize Price} = \alpha + \beta\,\textit{Year} + \varepsilon \tag{6}$$

$$\textit{Annual Producer Soybean Price} = \alpha + \beta\,\textit{Year} + \varepsilon \tag{7}$$

$$\textit{Global Beef Price} = \alpha + \beta\,\textit{Year} + \varepsilon \tag{8}$$

Using an OLS model, each variable was forecasted by accounting for a trend. The OLS trend model was a more realistic predictor of prices than a lag dependent variable was. The carcass weight structural model was forecasted next using data from 1991-2018 because of limited historical data for maize and soybean prices.

Considering the variety of factors affects weaning percentage (as mentioned in the literature review), weaning percentage was forecasted as follows:

$$\textit{Weaning Percentage} = f\,(\textit{Number of Cows, Global Beef Price, Average Monthly Rainfall, Trend, Trend}^2) \qquad (9)$$

Weaning percentage is a function of the number of cows, global beef price, annual rainfall, trend, and trend^2. An OLS model was also used to forecast weaning percentage. Weaning percentage data used ranged from 1983 to 2018 due to variability and reliability of the data. Prior to running the structural model number of cows and annual rainfall were individually forecasted out 50 periods (years), as annual Brazilian projections are not currently available.

The number of cows data was calculated from Production, Supply, and Distribution data (PS&D) (USDA, Foreign Agricultural Services 2018). Equation 3 was used to calculate the number of cows. Monthly rainfall data for Brazil was obtained from The World Bank database (The World Bank Group 2018). Once data was collected the exogenous variables were individually forecasted. Global beef price was not forecasted in this step as the results from the individual forecast utilized in the carcass weight structural model were incorporated into the weaning percentage structural model. The number of cows was forecasted using an OLS trend model as follows:

$$\textit{Annual Number of Cows} = \alpha + \beta\,\textit{Year} + \varepsilon \qquad (10)$$

A seasonal index model was used to forecast the monthly rainfall data series.

Scenario 2 implies that over the next 50 years Brazil's carcass weights and weaning percentages are increasing due to potential adoptions of new production management techniques or technologies.

Scenario 3

The purpose of scenario 3 is to determine the rate of change Brazil needs to meet each year to reach current U.S. targets for carcass weights and weaning percentages, implying greater efficiency. As of 2016, FAO of the United Nations (2018) calculated the average U.S. meat, cattle carcass weight to be 810.86 pounds. However, the FAO calculated average may not be as precise of a calculation as it is unclear what or if all cattle are included (i.e. commercial, federally inspected, etc.) According to the USDA, National Agricultural Statistics Service (2016) the average carcass weight in 2016 was 829 lbs. for federally inspected cattle. As of August 2018, the average dressed weight for federally inspected cattle was approximately 819 lbs. (USDA, National Agricultural Statistics Service 2018). With FAO and USDA numbers in mind, a U.S. target weight to be reached by Brazil at the end of 50 years was set to 814 lbs.

In regards to weaning percentage, the weighted average from 2012-2016 in New Mexico, Oklahoma, and Texas was 83.5% (Texas A&M Agrilife Extension Beef Cattle SPA 2016). The 2015 Nebraska Beef Cattle Report indicated a 95% weaning percentage (Warner et al. 2015). Based off of Texas A&M Agrilife Extension Beef Cattle SPA (2016) a U.S. target of 85% was set for Brazil to reach at the end of 50 years.

After the targets of 814 pounds and an 85% weaning percentage were set, the unit change required for Brazil to reach each U.S. target was calculated:

$$\textbf{\textit{Brazil Annual Carcass Weight Change}} = \textbf{\textit{(U.S. Target Weight – 2018 Brazilian Carcass Weight) / 50 Years}} \quad (11)$$

$$\textbf{\textit{Brazil Annual Weaning Percentage Change}} = \textbf{\textit{(U.S. Target Weaning \% - 2018 Brazilian Weaning \%) / 50 Years}} \quad (12)$$

Scenario 3 focuses on Brazil adopting new production management techniques and technologies consistently in order to achieve current U.S. values. 50 years from now U.S. carcass weights and weaning percentages could be significantly different than what they are today. Fortunately, this model allows for target values to be easily adjusted if desired. For the purpose of the current study, the focus will remain on achieving *current* U.S. values.

Scenario Comparison

Results of all three scenarios were compared to determine the impact on production by year 2068. Brazilian cow numbers were assumed to remain constant to allow for a calf crop value to be calculated based on the weaning percentage in each scenario. Each calf crop was then multiplied by the carcass weight in each scenario. The impact due to increases in efficiency on production was then evaluated by considering a variety of scenario combinations for carcass weights and weaning percentages.

CHAPTER IV

RESULTS

Analyzing three different scenarios allows one to determine how varying levels of efficiency can impact Brazilian beef production.

Initial Calculation Results

The initial calculations served as a foundation for analyzing the impacts of increased efficiency. According to the calculations made, in 1960 Brazilian average cattle carcass weight was 415.7 lbs./head, and by 2018 carcass weight had increased by approximately 31.6% to 547.2 lbs./head (USDA, Foreign Agricultural Services 2018). Figure 1 shows the gradual increase in Brazilian carcass weights from 1960 to 2018.

It's evident that 1981-1987 was a period of low carcass weights. From 1979-1980 there was a drastic change in the number of total cattle slaughtered, which influenced carcass weights. Cattle slaughtered went from 10.05 million head in 1979, to 15.79 in 1980, and finally to 19.4 in 1981 before resuming a gradual increase (USDA, Foreign Agricultural Services 2018). Naturally, there was a significant increase in production from 1979-1980, 2.1 million metric tons (MMT) to 3.29 MMT, which offset the increase in total slaughter; thus, not drastically changing carcass weight. However, the slight increase in production in 1981 to 3.43 MMT was not substantial enough to offset the increase in total slaughter from 15.79-19.4 million head resulting in a lower carcass weight of 389.6 lbs./head. Carcass weight did not return to over 450 lbs./head until 1987 when production increased from 3.84 MMT in 1986 to 4.73 MMT in 1987. At the same time, total slaughter increased from 21.4 million head to 23.0 million head. An explanation for the change in the number of head slaughtered and production values could be the result of responses to global beef prices and the export market. In 1980 global beef prices were $1.25/lb. (Federal Reserve Bank of St. Louis 2016), as a result producers may have expected similar prices in 1981 leading them to sell more cattle and at potentially lighter weights to capitalize on higher prices. Therefore, there was an increase in the number of total cattle slaughtered, but production did not increase in the same proportion. Global beef prices remained above $1/lb. from 1980 to 1984 (Federal Reserve Bank of St. Louis 2016). By 1986 prices fell to $0.95/lb. (Federal Reserve Bank of St. Louis 2016) and exports declined in 1987. While total number of animals slaughtered continued to gradually increase there was not as extreme of a jump as there was in 1980; in addition, total production also increased causing average carcass weights to rise back up past 450 lbs./head in 1987. After 1985 productivity started to account for the majority of the production growth (Martha, Alves, and Contini 2012). Table 1 depicts the aforementioned value changes.

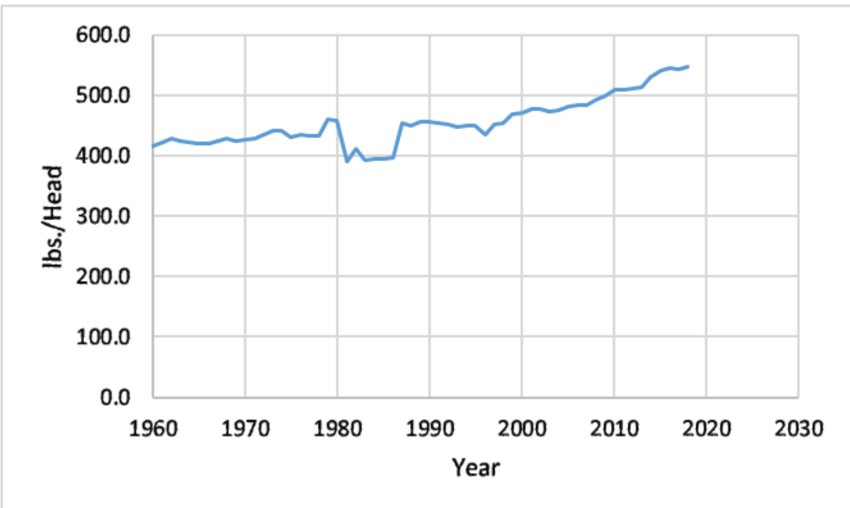

Figure 1. Brazilian carcass weights, 1960-2018
Source: (USDA, Foreign Agricultural Services 2018)

Table 1. Brazilian Beef Production Data, 1979-1987

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	Unit
Total Slaughter	10,050	15,793	19,400	19,200	19,600	20,500	20,700	21,400	23,000	*(1,000 Head)*
Meat, Beef, Veal Production	4.63	7.24	7.56	7.91	7.71	8.11	8.17	8.47	10.43	*(Billion lbs. CWE)*
Meat, Beef, Veal Exports	242.51	416.67	694.46	877.44	992.08	1,119.95	1,183.88	857.60	707.68	*(Million lbs. CWE)*
Global Beef Price	-	1.25	1.12	1.08	1.11	1.03	0.98	0.95	1.08	*($/lb.)*
Carcass Weight	461	459	390	412	393	395	395	396	453	*(lbs./hd.*

Note: The Brazilian Beef Production Data chart includes total number of head slaughtered, total production, total exports, and the global beef price.
Source: (USDA, Foreign Agricultural Services 2018; Federal Reserve Bank of St. Louis 2016)

According to the implied weaning percentage calculation made (equation 4.) in 1975 the Brazilian weaning percentage was 29.49%. In 2018 the weaning percentage had increased by approximately 7% to 31.6% (USDA, Foreign Agricultural Services 2018). Figure 2 displays the slow increase in weaning percentages. In 1984 there was a significant drop to 16.19%, primarily due to a drastic increase in the total number of cows (equation 3.). Total number of cows increased from 37.5 million head in 1982 to 78.5 million head in 1983 (USDA, Foreign Agricultural Services 2018). While it is unclear what caused the extreme jump in data, it could be a result of changing data collection methods.

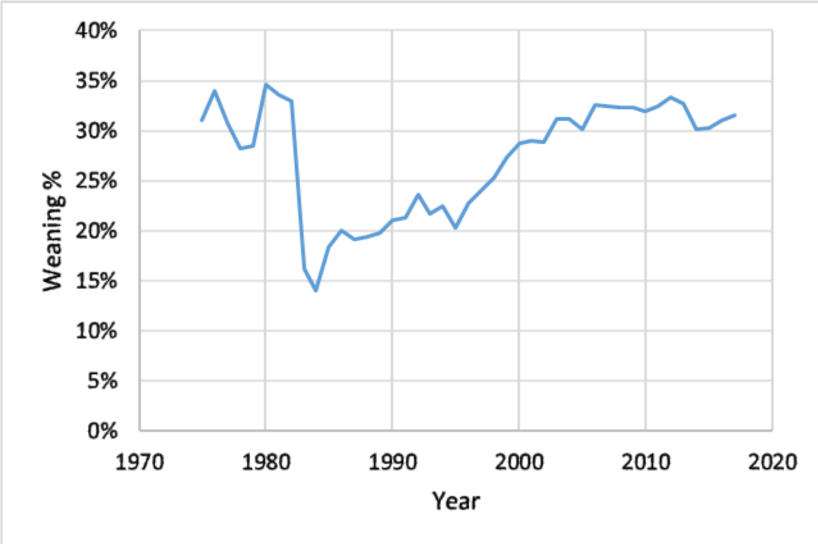

Figure 2. Brazilian weaning percentage, 1975-2018
Source: (USDA, Foreign Agricultural Services 2018)

Scenario 1 Results

Scenario 1 assumes that Brazil does not change production practices, i.e., there is no increased efficiency over 50 years. Scenario 1 implies that Brazil would maintain their current (2018) carcass weight and weaning percentage (547.2 lbs. and 31.6% respectively). The constant values will be referred to as the "Baseline."

Scenario 2 Results

The purpose of scenario 2 was to determine how changes in related factors or the adoption of new production practices and technologies could impact carcass weights and weaning percentage. Prior to developing the model, the exogenous variables for carcass weight had to be individually forecasted through trend models. The models provided the following results:

Table 2. Maize, Soybean, & Global Beef Price OLS Regression Statistics 1

	Beta & Prob(t)	Intercept	Year
Maize Price Model	*Beta*	**(8,720.533)**	**4.4224**
	Prob(t)	0.0001	0.0001
Soybean Price Model	*Beta*	**(23,966.509)**	**12.0924**
	Prob(t)	0.0000005	0.0000004
Global Beef Price Model	*Beta*	**-0.7573**	**0.0001**
	Prob(t)	0.0964	0.0001

Note: Beta coefficients and level of significance data for Maize, Soybean, and Global Beef Price models are included in the Maize, Soybean, & Global Beef Price OLS Regression Statistics 1.

Table 3. Maize, Soybean, & Global Beef Price OLS Regression Statistics 2

	Maize Price Model	Soybean Price Model	Global Beef Price Model
F-test	23.236	47.525	19.854
R^2	0.492	0.664	0.362
MAPE	20.781	23.788	21.112

Note: Maize, Soybean, & Global Beef Price OLS Regression Statistics 2 presents the F-test, R^2, and MAPE results for each respective model.

The Maize Price Model classifies the Year variable as being statistically significant as evident by its Prob(t) value. However, the model has a low R^2. The model shows a low trend in the data. At the same time, the trend model provided a more realistic forecast than a lagged dependent variable model. The same holds true for the subsequent models.

The soybean price model also denotes Year as being statistically significant. The R^2, while not ideal, is still higher than the maize and global beef models, indicating a better goodness of fit. Finally, the Year variable is also statistically significant within the global beef price model. Unfortunately, the global beef price model displays an extremely low R^2. As mentioned previously though, a trend model proved to be the best option for the purpose of the current study.

After the exogenous variables were individually forecasted the results were applied to a structural model to predict carcass weights:

Table 4. Estimated Brazilian Cattle Carcass Weight and Model Goodness of Fit Measures-Scenario 2 (Unrestricted)

	Intercept	**Maize Price**	**Soybean Price**	**Global Beef Price**	**Trend**	**Trend^2**
Beta	**444.835**	(0.060)	(0.040)	**11.978**	**1.243**	**0.102**
Prob(t)	0.000	0.268	0.177	0.019	0.027	0.000
F-test	232.458					
R2	0.981					
MAPE	0.738					

Note: The Unrestricted Carcass Weight Scenario 2 model summarizes the results associated with the Carcass Weight Structural Model.

The unrestricted carcass weight model indicates that the Global Beef Price, Trend, and Trend^2 variables are statistically significant. However, the exponential trend variable (i.e., Trend^2) resulted in an unrealistically high forecasted carcass weight in 2068 of 1,164.77 lbs. As a result of the unrealistic forecast associated with the unrestricted model, the Trend^2 variable was restricted; thus, providing the following results:

Table 5. Estimated Brazilian Cattle Carcass Weight and Model Goodness of Fit Measures-Scenario 2 (Restricted)

	Intercept	**Maize Price**	**Soybean Price**	**Global Beef Price**	**Trend**
Beta	**420.952**	(0.058)	(0.038)	**24.231**	**3.688**
Prob(t)	1.11806E-28	0.4640	0.3757	0.0006	2.23931E-10
F-test	132.287				
R2	0.958				
MAPE	1.114				

Note: The Restricted Carcass Weight Scenario 2 model summarizes the results associated with the Carcass Weight Structural Model.

The restricted structural model indicates that both Global Beef Price and Trend are statistically significant, as evident by their Prob(t) values (Table 5). At the same time, each variable exhibits the sign consistent with economic theory. The model produced similar results as Langemeier and Thompson (1967) in which dressed weights had a positive relationship with beef prices and an inverse relationship with corn prices. Soybean price also displayed an inverse relationship with carcass weights; thus, following consistent theory as it represents an input price. The Trend variable indicates that there is a positive linear trend in the model. Further analysis concludes a desirable goodness of fit for the model. The high R^2, coupled with a more desirable F-test than the unrestricted model, confirm the goodness of fit.

In conclusion, scenario 2 forecasted carcass weights for the next 50 years by taking into consideration maize price, soybean price, global beef price, and trend exogenous factors. Based off of the model, by 2068 Brazilian carcass weights are expected to be roughly 707 pounds. Current Brazilian average carcass weight is 547.21 pounds (USDA, Foreign Agricultural Services 2018); thus, resulting in an approximately 29% increase from 2018.

Next, weaning percentages were also forecasted out 50 years. To account for a variety of factors that may impact weaning percentages number of cows, global beef price, average monthly rainfall, trend, and $trend^2$ exogenous variables were initially included in the structural model. Prior to developing the model, the number of cows and average monthly rainfall exogenous variables for weaning percentage were individually forecasted through a trend and seasonal index model. The models provided the following results:

Table 6. Number of Cows OLS Regression Statistics

	Intercept	**Year**
Beta	**(1,477,964.507)**	**778.199**
Prob(t)	0.000	0.000
F-test	91.168	
R2	0.728	
MAPE	4.570	

Note: Beta coefficients and level of significance data for the Number of Cows OLS Regression.

Table 7. Average Monthly Rainfall Trend Regression Statistics

	AVERAGE
Intercept	5.758615
Slope	0.002476
R-Square	0.008092
S.E.	0.004701
T-Test	0.526669
Prob(T)	0.601746
S.D. Residuals	0.288811

Note: Beta coefficients and level of significance data for the Average Monthly Trend Regression Statistics.

The Year variable for the Number of Cows OLS trend model was statistically significant and indicated a positive linear trend over time. The model also displayed a relatively low goodness of fit as evident by the R^2 value (Table 6.) In regards to the Average Monthly Rainfall trend regression, the slope indicated a positive linear trend; however, the slope was insignificant. After the exogenous variables were individually forecasted the results of the models were incorporated into a structural model for weaning percentage. The results of the unrestricted structural model are as follows:

Table 8. Estimated Brazilian Weaning Percentage and Model Goodness of Fit Measures-Scenario 2 (Unrestricted)

	Intercept	**# Cows**	**Global Beef Price**	**Average Monthly Rainfall**	**Trend**	**Trend2**
Beta	(0.150)	**0.0000052**	(0.019)	(0.006)	**0.009**	**(0.0002)**
Prob(t)	0.411	0.007	0.518	0.758	0.002	0.032
F-test	17.994					
R2	0.750					
MAPE	7.650					

Note: A summary of the Beta Coefficient and Prob(t) values are included in the Unrestricted Weaning Percentage structural model.

The results of the unrestricted weaning percentage model indicate that the Number of Cows, Trend, and $Trend^2$ variables are statistically significant. The beta coefficient sign associated with the number of cows specifies a positive relationship with the weaning percentage. The positive relationships indicates that as producers increase their cattle herd focus is also being placed on improving the weaning percentage. However, a justifiable explanation also exists if the beta coefficient would have been negative. The alternate explanation for a negative coefficient would assume that as cattle herds increase it becomes more difficult to manage more cattle; thus, causing a negative effect in weaning percentages. In addition, considering that weaning percentages are merely a percentage of the number of cows the final conclusion was drawn that the number of cows is not a proper indicator of weaning percentages. Number of cows was restricted in the final model. Global beef price, Average Monthly Rainfall, and $Trend^2$ were restricted as well for the following reasons:

Global beef price displayed a negative coefficient inconsistent with economic theory and was not statistically significant. Average Monthly Rainfall denotes rainfall for the entire country. For the rainfall data to provide accurate and significant results rainfall data would have to be collected only in regions were cattle production occurs. Average Monthly Rainfall was also found to be insignificant. Finally, the $Trend^2$ variable represented a negative exponential trend resulting in negative forecasted values.

After the potential issues associated with the unrestricted model were identified, the model was restricted by incorporating solely a Trend variable. Weaning percentage can be affected by many complex components such as genetics, management/breeding decisions, and the environment, making it challenging to forecast percentages (Reiling 2011). Furthermore, little to no research has been done on weaning percentages making it even more problematic. The results of the restricted model are as follows:

Table 9. Estimated Brazilian Weaning Percentage and Model Goodness of Fit Measures-Scenario 2 (Restricted)

	Intercept	**Trend**
Beta	**0.181**	**0.004**
Prob(t)	3E-17	9E-10
F-test	70.266	
R^2	0.674	
MAPE	9.068	

Note: A summary of the Beta Coefficient, Prob(t), F-test, R^2, and MAPE values are included in the Restricted Weaning Percentage Scenario 2 model

The time Trend is positive and statistically significant. Trend represents weaning percentages as having a positive linear trend over time, which assumes that Brazil is striving to improve management practices to accomplish higher rates. 2018 Brazilian implied weaning percentage is 31.6% and in 2068 the model forecasted the weaning percentage to be 56.77%, resulting in an 80% increase.

Scenario 3 Results

Scenario 3 focuses on Brazil achieving U.S. levels of efficiency by meeting current carcass weights and weaning percentages. The scenario implies that Brazil is increasing efficiency at a constant rate over the next 50 years. As previously discussed, the target weights and percentages are 814 lbs./head and 85% respectively. Knowing that current (i.e., 2018) Brazilian carcass weights and weaning percentages are 547.22 lbs./head and 31.6%, equations 11 and 12 were used to determine how much each would have to change annually to reach U.S. targets (USDA, Foreign Agricultural Services 2018).

It is necessary for yields to increase by 5.3356 lbs./head/year to reach current U.S. carcass weights by year 2068. Weaning percentages would have to increase by 1.068 percentage points a year.

Scenario Comparison Results

Figure 3 provides a visual of the three scenarios over time. Scenario 1 represents no increased efficiency- or the baseline, Scenario 2 yields to improved efficiency/productivity but also accounts for factors affecting carcass weights, and Scenario 3 implies increasing efficiency and productivity enough each year to reach current U.S. levels of 814 lbs./head. Whether or not *Bos indicus* cattle are able to achieve an 814 lb. carcass will require additional research surrounding genetics. Crouse et al. (1993) analyzed the impact on carcass characteristics and palatability due to different *Bos indicus* inheritance levels. They found the *Bos indicus* crosses were lighter than Pinzgauer and Angus-Hereford Crosses. The results contradict the previous phase in which *Bos indicus* crosses were heavier than Angus-Hereford cross steers. The results suggest that it is heterosis effects, not additive gene effects that led to higher growth of the *Bos indicus* cattle in the prior phase. The cattle in the study were grain fed.

In scenario 2 there is a slight decline in carcass weights from 2018-2019. The reason for the jump is that the graph includes an observed value in 2018, and in 2019 the model begins forecasting; therefore, adjusting for any error.

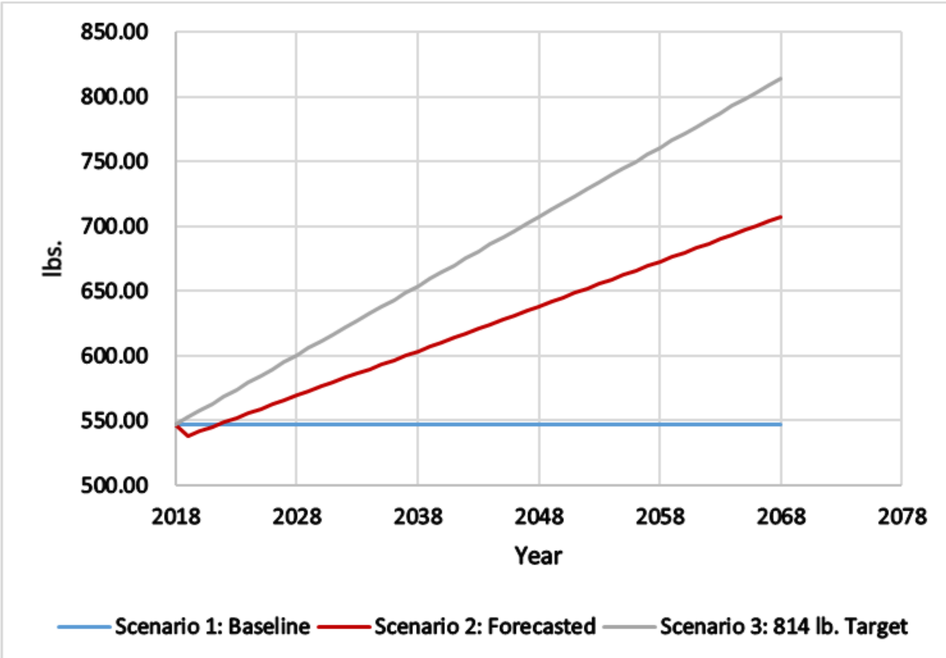

Figure 3. Brazilian carcass weight scenarios, 2018-2068

Figure 4 provides a visual of the same three scenarios but adjusted to represent weaning percentages over time. Just as in figure 3, figure 4 also displays a jump in the scenario 2 data. Once again, the graph includes an observed value in 2018, and in 2019 the model begins forecasting; therefore, adjusting for any error and causing the data to rise before continue a constant upward trend. Whether or not Brazil will be able to achieve current U.S. weaning percentage rates by 2068 depends on how quickly Brazil adopts new production management practices.

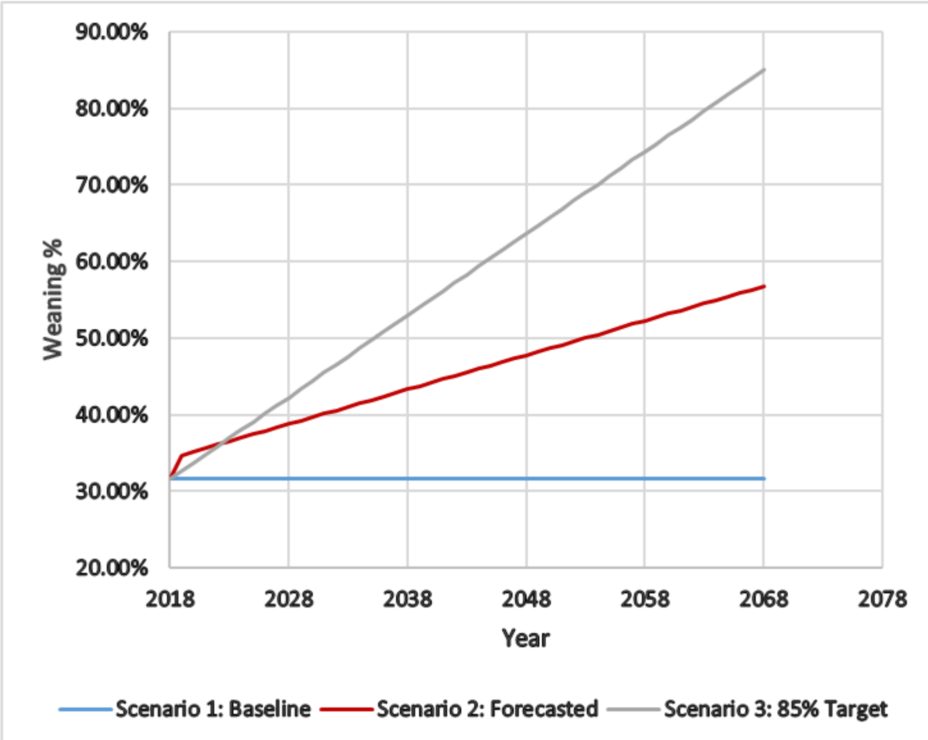

Figure 4. Brazilian weaning percentage scenarios, 2018-2068

As discussed, increases in efficiency lead to increases in production. In particular, increases in both productivity and the number of animals increases livestock production (Thornton 2010). To determine the actual potential impact of each different efficiency scenario on production by year 2068, production was analyzed at the three different weaning percentage levels. Calf crop was calculated for each weaning percentage level and multiplied by the different levels of carcass weights. Calf crop was calculated assuming constant total number of cows from 2018-2068. The number of cows in 2018 is 97.5 million head (USDA, Foreign Agricultural Services 2018).The number of cows was multiplied by the weaning percentage being evaluated to receive an estimated calf crop. The calculations allowed production to be analyzed in a variety of scenario combinations for carcass weights and weaning percentages: no change in carcass weight and weaning percentage (i.e. Baseline), an increase in efficiency in both carcass weights and weaning percentages (Scenario 2 & 3), an increase in carcass weight but no change in weaning percentage, and an increase in weaning percentage but no change in carcass weight. Table 10 and figure 5 provide the results of the analysis:

Table 10. Brazilian Beef Production Scenario Comparison, 2068

	Calf Crop (Million head)	Carcass Weight (lbs./head)	Total Beef Production (Billion lbs.)	Production Growth (%)
Weaning Percentage: 31.6%	30.19	547.22	16.52	0%
	30.19	707.43	21.35	29%
	30.19	814.00	24.57	49%
Weaning Percentage: 56.77%	55.35	547.22	30.29	83%
	55.35	707.43	39.16	137%
	55.35	814.00	45.06	173%
Weaning Percentage: 85%	82.88	547.22	45.35	175%
	82.88	707.43	58.63	255%
	82.88	814.00	67.46	308%

Note: 2068 Brazilian Beef Production Scenario Comparison chart assumes constant total cow numbers. The chart illustrates the impact varying levels of weaning percentages and carcass weights have on Brazilian beef production. Production growth represents a % change in production from 2018 or the Baseline.

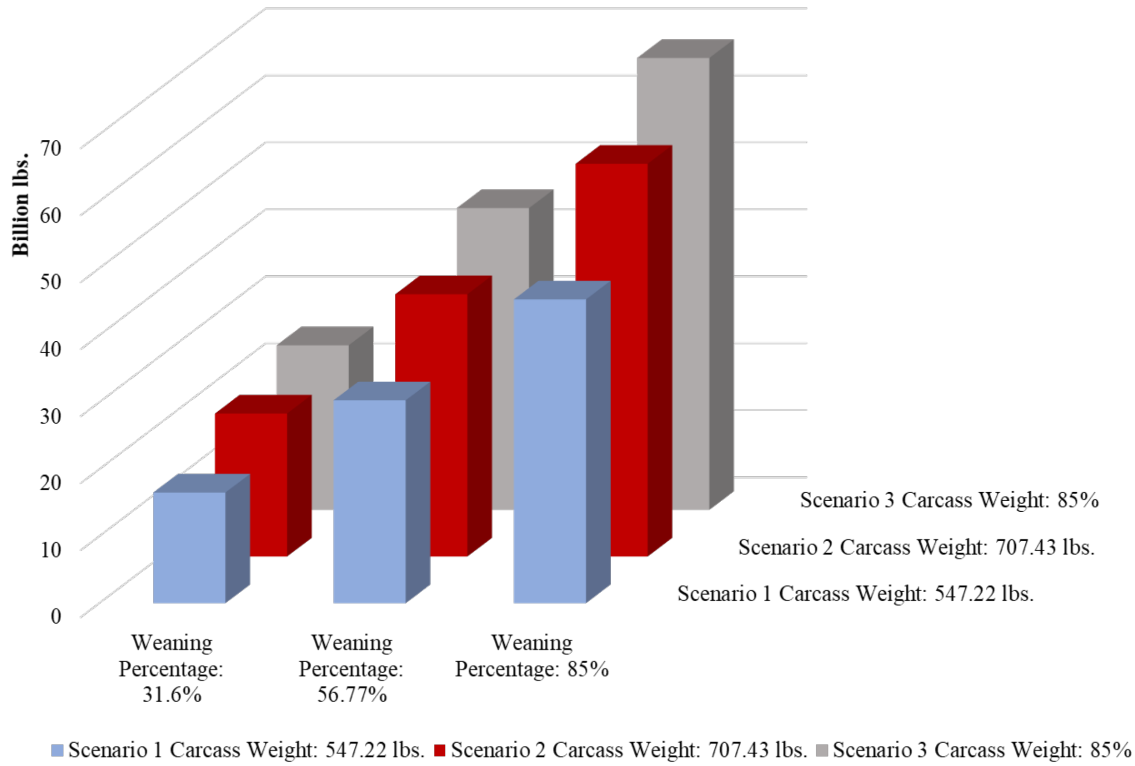

Figure 5. Potential Brazilian beef production, 2068

If Brazilian weaning percentages achieved either scenario 2 or 3's levels by 2068 but carcass weights remained constant, beef production would increase from 16.52 billion pounds to 30.29 billion pounds in scenario 2, and 45.35 billion pounds in scenario 3. Resulting in an 83% and 175% increase in beef production respectively. If productivity were increased in both the cow-calf and grazing or finishing sectors based off of scenario 2's forecasted results, beef production would have the opportunity to increase from 16.52 billion pounds to 39.16 billion pounds exhibiting a growth of 137%. Meeting current U.S. levels by year 2068 Brazil would approximately increase beef production to 67.46 billion pounds. In 2018, the U.S. has produced roughly 27.78 billion pounds with 40.56 million head of dairy and beef cows and an estimated calf crop of 27.68 million head (USDA, Foreign Agricultural Services 2018). While Brazil has produced approximately 21.83 billion pounds with 97.5 million head of dairy and beef cows and an estimated calf crop of 30.19 million head (USDA, Foreign Agricultural Services 2018). Clearly, Brazil's advantage in the numbers of their commercial cow herd could set them apart 50 years from now; should Brazil become more efficient in cattle production. Note, Brazil would have to have a price and demand incentive to increase productively to current U.S. levels. If incentives did not exist Brazil could potentially lose money by increasing beef production due to potential low beef prices.

CHAPTER V

CONCLUSIONS

Efficiency in Brazilian cattle production can be achieved both in the cow-calf and finishing sectors. Particularly through increasing carcass weights and weaning percentage over time. Knowing that Brazil's grain production is continuing to increase substantially, Brazil could divert a portion of their crop to feeding more cattle in the future, which would aid in increasing carcass weights. However, feeding cattle would have to prove profitable for Brazil to feed their grain rather than exporting it or using it for other domestic purposes. As discussed previously, weaning percentages would have to be increased either through genetics or additional management practices to improve herd health and mitigate environmental factors.

Increasing carcass weight or weaning percentages can lead to drastic increases in production, making Brazil even more competitive. Depending on the rate at which the U.S. increased beef production, Brazil could even have the potential to surpass the U.S. as the number one beef producer in the world. Aside from reaching current U.S. levels, the greatest gain in production would come from increasing both carcass weights and weaning percentage to 707.43 lbs. and 56.77% respectively. Reaching 707.43 lbs./head and a percentage of 56.77% levels by 2068 represents a 137% increase from the value of production when both variables are held constant.

The results of the current study could be expanded to analyze how changes in Brazil's beef supply would affect U.S. beef producers. Cattle prices are primarily determined by supply and demand in the long run. Changes in both domestic or foreign demand and supply can drastically influence the U.S. beef industry. Understanding how future changes in a major beef competitor (i.e., Brazil) could influence our beef producers becomes necessary.

Other options for further study include decomposing the results from the current study into two components: grass-fed and grain-fed. i.e. How many additional cattle will Brazil need to have on grass to achieve the new level of beef production, and by how much will the stocking rate need to increase? Alternatively, how many more bushels of grain will need to be fed to achieve the new level of production? Finally, a cost benefit analysis could be developed to determine if feeding Brazil's increased grain production to increase efficiency in beef production (i.e., carcass weights) or simply exporting the grain would be more profitable.

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APPENDIX A

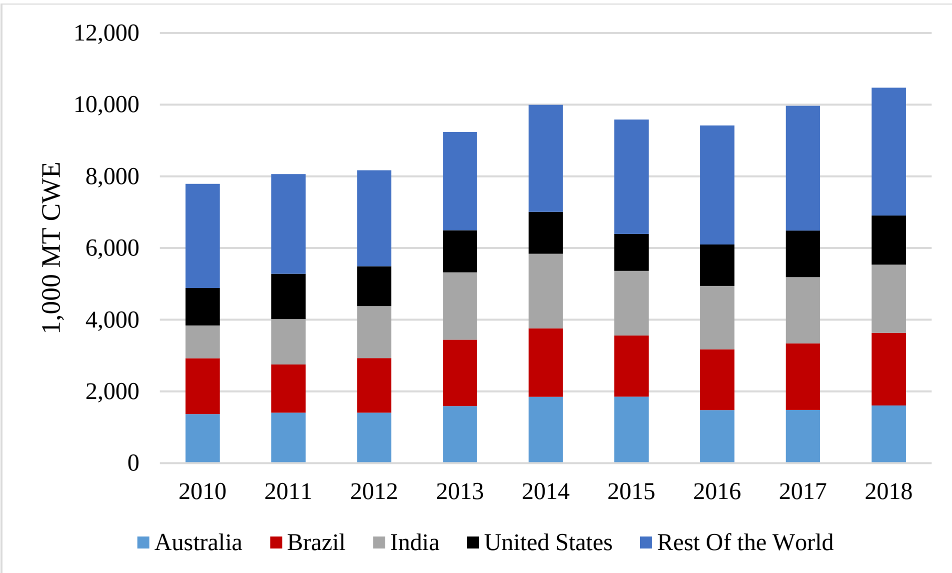

Figure A-1 World beef exports
Source: (USDA, Foreign Agricultural Services 2018)

Figure A-2 The sustainable Brazilian beef
Source: Reprinted from (Brazil, Brazilian Beef Exporters Association 2018)

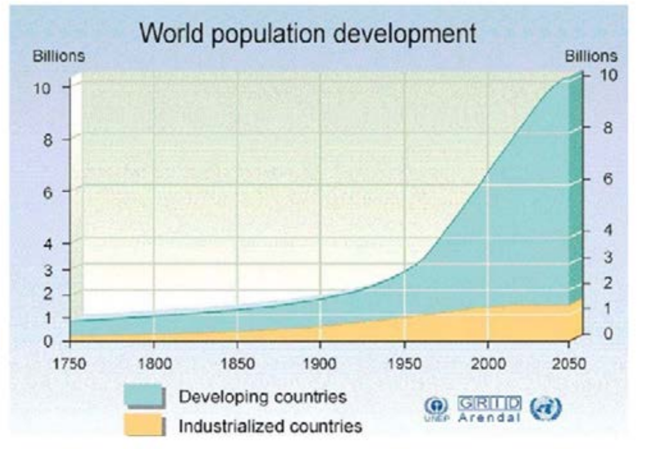

Figure A-3 World population development
Source: Reprinted from (Rekacewicz 2005)

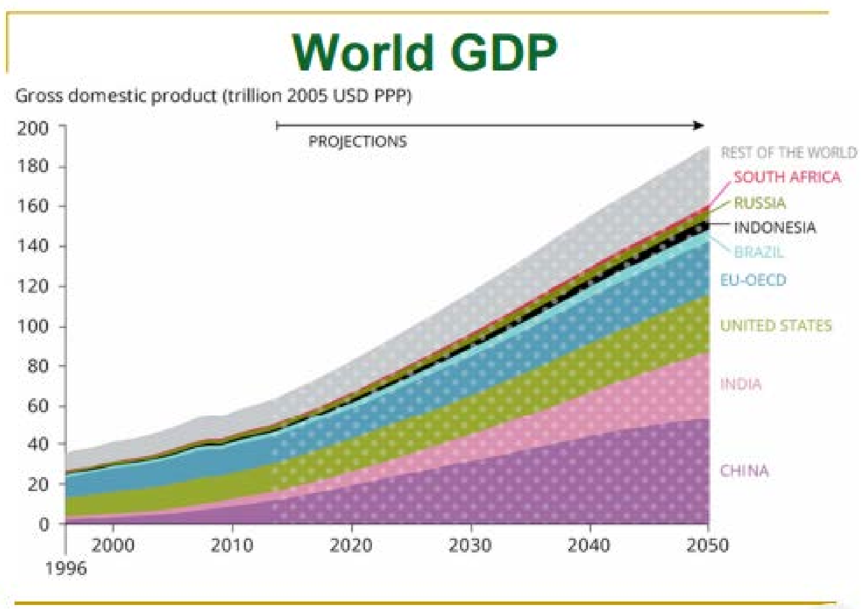

Figure A-4 World GDP
Source: Reprinted from (European Union, European Environment Agency 2017)

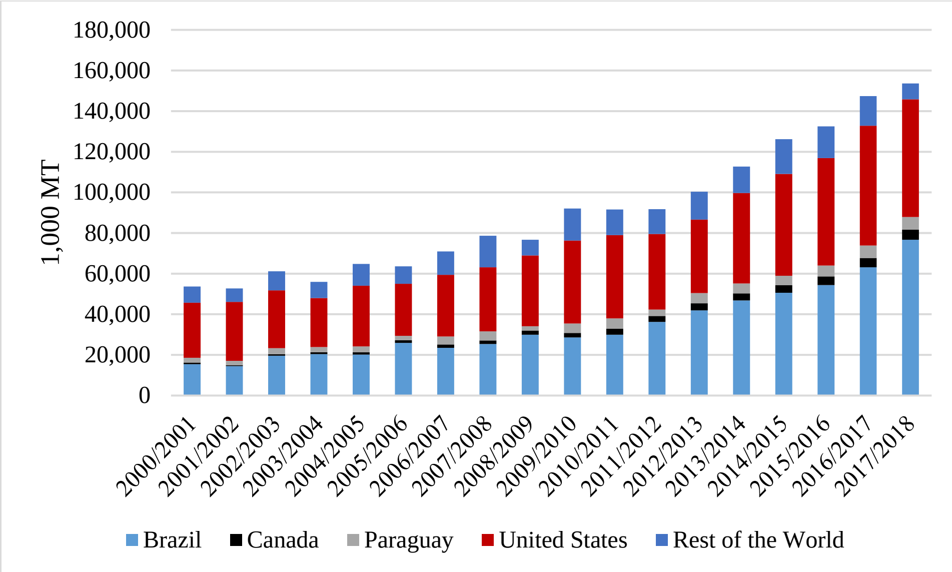

Figure A-5 World Soybean Exports
Source: (USDA, Foreign Agricultural Services 2018)

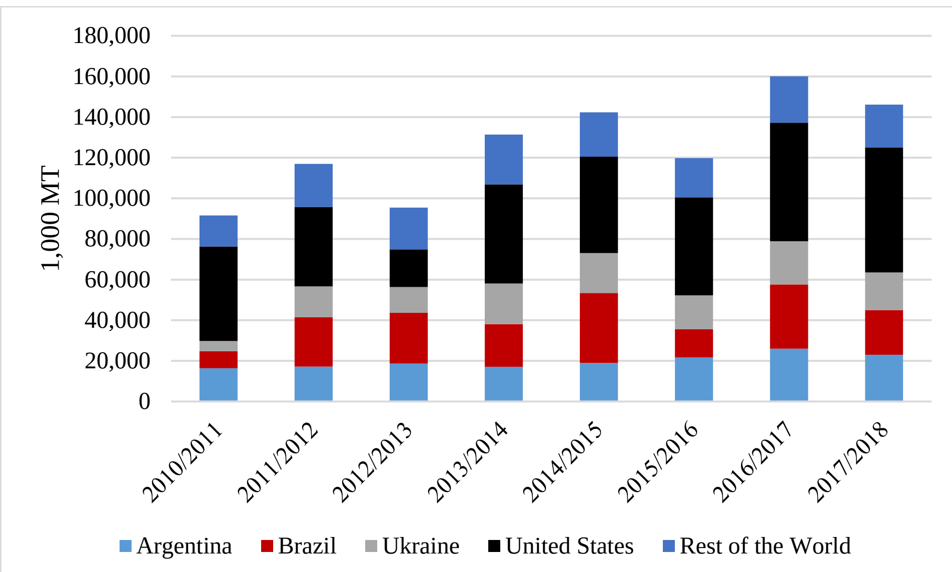

Figure A-6 World Corn Exports
Source: (USDA, Foreign Agricultural Services 2018)