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Time Series Forecast Analysis in Wholesale Broiler Markets

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Time Series Forecast Analysis in Wholesale Broiler Markets

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Abstract

In 2016 the chicken industry provided nearly 1.2 million jobs, 68 billion dollars in wages, 313 billion dollars in economic activity and 24 billion dollars in government revenue (John Dunham & Associates, Inc., 2016). Broiler production has changed dramatically from the early 90's to the turn of the 21st century. Technological advancements, continuous improvements, production efficiencies and industry changes have made the industry the global market it is today. The poultry industry is an extremely volatile market with prices constantly fluctuating in response to input price volatility and demand and supply changes. These changes are often driven by world economic conditions which impacts the roughly 20% of U.S. production that is exported. Due to these variations, accurate forecasting of poultry prices is difficult.

Economic modeling is complex at best; this paper examines a comparison between vector autoregression (VAR) and autoregressive (AR) techniques. Urner Barry average monthly northeast wholesale poultry parts price data was used for this research. Parts analyzed are; drumstick (DRUM), jumbo boneless skinless breast tender out (BSBTO), leg quarter (LQ), thigh (THIGH), small wing (SMWING), jumbo wing (JMWING), tender (TENDER) and whole bird without giblets weighing 2 ¼ lbs. (WOG). This modeling will focus on the technical aspects of modeling to initiate a strong foundation for further research. Key fundamental aspects are discussed to give economical understanding of the challenges the broiler industry faces. This research concludes that AR modeling is superior to VAR modeling techniques.

It is important for the broiler industry to understand pricing strategies for contracts with food retail operators[1]. Price forecasting has the potential to help poultry companies increase their

[1] Food retail operators are business within the foodservice industry such as McDonalds, Kentucky Fried Chicken, Taco Bell, and Sonic.

returns on revenue. Wholesale broiler parts today are extensively further processed and value added today than in previous years. This causes the wholesale price to have little influence in processors determined price within contracts. Knowing price interaction will allow processors to determine alternate cuts of meat that can be substituted for products during times of high prices.

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Dedication

I would like to dedicate my thesis to my family and friends that have been my supporters throughout the entire process. I am forever greatful for their profound support, words of encourangement, and always being there for me.

Special thank you to my family for their support as I became the first college graduate from our family, and continued my education through my masters program. Their continuous support and guideance throughout school and life has left me with many lessons that I will never forget. They have pushed me to be successful in everything that I do and continue to always be looking forward for constant progress in life.

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Section I - Introduction

Current Pricing Situation and Importance

Poultry companies have evolved their pricing strategy with the ever-changing market and consumer base and have expanded their product portfolios beyond traditional whole/rotisserie chicken, 8-piece cut-up[2], and tray pack[3]. The chicken business has expanded beyond only retail customers to encompass foodservice establishments as well. In the 80's companies began to see a shift of consumers wanting further processed value-added[4] products. The shift comes from changes in consumers taste, preferences, and lifestyles.

The U.S. broiler industry is rapidly evolving from where it was 15, 10 and even 5 years ago, at the turn of the century. It has grown to have a global presence. Issues that affect the industry now have an even bigger impact than before. Companies have evolved with the help of technological advancements to increase production and efficiencies. Broiler industry expansion has been growing at an increasing rate and is important to the United States economy. Over the years, broiler consumption rose slowly and in 1993 surpassed individual consumption of beef or pork (National Chicken Council, 2017). In the decade of the 90's, ready to cook (RTC) broiler[5] pounds produced increased nearly 10 billion pounds (National Chicken Council, 2017). Consumers' behaviors began to change with their tastes and preferences, prompting the increase in broiler consumption.

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[2] This refers to the way a bird is cut-up and offered to consumers. Two of each of the following pieces comes from the bird once cut-up; breast halves, wings, thighs, and drums. (United States Department of Agriculture, 2000).

[3] Poultry that is fresh packed on a tray and then individually wrapped tightly with a plastic film. (Dawson, 2008).

[4] Further processed value added food products have been changed physically in a way to enhance the value of the original product. (University of Maryland Extension, 2017).

[5] Processed young poultry and its parts which are ready to be cooked with very little additional preparation (The Poultry Site, 2003)

In the 50's there were over 200 broiler companies. By the 90's and early 2000's, several acquisitions and mergers had been completed within the industry. By 2000, there were fewer than 50 companies and as of 2017 there were only about 35. WATT PoultryUSA's January 2001 issue discusses the time of acquisitions for the industry as the top three companies slowly gained more share of the total industry (WATT Poultry, 2001). 2001 was a big year for the industry because numerous acquisitions occurred. Vertical integration has also been key to processors becoming more efficient in cost savings and production as they are today, continuing to give rise to the number of acquisitions within the industry. Increases in production efficiencies have allowed the development of more wholesale and retail product cuts to be offered.

"For decades, producers made their money on the front half of the bird but lost money on the back half," said Bill Roenigk, senior vice president and economist with the National Chicken Council (Business Insider, 2012). This began changing in the 1990s as the industry found new markets for the back half in Russia, Asia, and Latin America (Business Insider, 2012). Americans overwhelmingly desire white meat chicken portions over dark meat. This means the excess dark meat portions are exported out of the United States. Thus, white meat chicken parts are the drivers behind the pricing of all parts. In the past, consumers strongly preferred breast meat. In research conducted by Goodwin et al., investigating the usefulness vector autoregression models to explain chicken part pricing, they found "strong evidence suggests a significant price relationship between boneless skinless breast (BSB) and the whole carcass without giblets (WOG). Shocks in the BSB market have a great effect on WOG market prices compared with price shocks resonating within dark meat markets" (Goodwin, Jr., McKenzie, & Djunaidi, p. 483-495, 2003). Breast meat has led the pricing strategy for all other parts. However, over the years, volatility in prices of all parts has been increasing and consumer preferences are shifting to alternate chicken products. Parts pricing is extremely important for processors to understand when negotiating contract base prices with customers. Prices are listed by unbiased third party vendors, which give integrators (Pilgrim's Pride, Tyson Foods, Perdue, etc.) a benchmark, which they use to base their formula price on when determining customers' contract prices. Third-party vendors give integrators a full perspective of overall market potential and the market's direction to inform future price negotiations.

Problem Statement

Broiler parts prices are in a constant state of price volatility due to external factors playing a crucial role in final parts pricing. Thus, accurately forecasting broilers prices into the future is difficult and with no consensus on the preferred forecast method. Better understanding the price interaction of broiler parts could change the way processors market individual parts. Being able to more accurately forecast broiler prices into the future would than other companies would provide the broiler company an added advantage for revenue growth and market capture. If such forecasts were public and shared among the involved parties, price discovery should become more efficient. More accurate price predictions also give broiler companies better directionality for further growth and internal strategies.

In economics, vector autoregression (VAR) models are commonly used as basis for building forecast models (Smith, Carter, & Rausser, 2017). Smith et al., utilize VAR models and "find partially identified VAR models to be a fruitful avenue for future research in price analysis" for market effects of biofuels (Smith, Carter, & Rausser, 2017). VAR model specifications require identifying the relevant variables chosen and the number of lags to use. Numerous factors play crucial roles in determining broiler prices. Some factors have an indirect relationship but still affect prices. The large market shares of chicken products the industry has in the foodservice category makes it extremely difficult to forecast prices, since prices are arranged by private negotiation and not reported publicly. Further processed, value-added products are extremely hard to connect back to the wholesale price of individual broiler parts due to the additional costs involved in making the changes necessary to produce the final products. This research compares VAR and single equation autoregressive (AR) models for relative forecasting accuracy. Both VAR and AR require selecting specifications of variables and lag lengths to analyze compare forecasting performance for each. Since AR models area subset of VAR models, the comparison essentially asks if the greater complexity of the VAR gives VAR an advantage over the simpler AR.

Objectives

Economic modeling approaches for the broiler industry are important and useful. The main thesis objective is to give insight into price forecasting for the broiler industry, thus allowing broiler companies to have a better understanding of how to interpret possible pricing strategies when negotiating contracts with food retail operators. Specific objectives include to: 1) Re-evaluate the VAR and AR modeling techniques used by McKenzie, Goodwin and Carreira to include updated Urner Barry wholesale parts pricing through May of 2017. A comparison using autoregressive (AR) versus vector autoregression (VAR) models will determine the superior modeling approach. 2) Determine if findings in McKenzie et al., still hold true given the changes the industry has undergone in responding to consumer demand. 3) If the findings differ, what does the new model suggest about changes in the industry? 4) Finally, determine if a specific broiler part drives all other parts prices.

Section II – Literature Review

Broiler Production and History in United States

Historical Background

Over a century ago, poultry farms were found on most all rural and many urban properties. The broiler industry began in the early 1900's with individual back yard hobby farms. Broiler meat was originally considered a byproduct from chickens with eggs being the key product. A few people started to sell chickens to help supplement their income on the side. In the late 20's and early 30's individuals start to have larger flocks of birds to sell for meat consumption. During this time, we see the rise of entrepreneurs with expansion of poultry farms throughout the Midwest states. "Mrs. Wilmer Steele of Sussex County, Delaware, is often cited as the pioneer of the commercial broiler industry. In 1923, she raised a flock of 500 chicks intended to be sold for meat. Her small business was so profitable, by 1926, Mrs. Steele was able to build a broiler house with a capacity of 10,000 birds" (National Chicken Council, 2012).

Between the 1940's and 1960's the broiler industry started to slowly take form. Birds were typically sold as "New York dressed," with just the blood and feathers removed. Broiler producers at this time had no single source for obtaining resources. With businesses growing, individuals began selling their own broilers. During the 1940's individuals began to start their own hatcheries, feed mills, and processing plants; entrepreneurs came in and started buying and consolidating to have ownership of every integral part of production. In the late 1940's policy, technology, market and production changes resulted in an increase in broiler meat sales. Now, the industry still focused on both egg and meat sales. In 1942, an Illinois plant was the first to gain government approval of "on-line" evisceration to pack birds into ice-filed containers. This change led to the government considering food safety programs. In 1949, the United States

Department of Agriculture (USDA) launched a voluntary program of grading birds to give consumers assurance of a high-quality product.

Entrepreneurs began to buy key entities for the industry to form into the 'vertical integration of today. Before this, all key broiler industry parts were owned by separate individuals, which resulted in higher costs. In 1952, the broiler industry became more commercialized, starting an economic boom for its participants. The classic meat chicken now known as the 'broiler bird' became the primary source for meat consumption. In the 1960's vertical integration became more widespread and slowly became the industry norm, strengthening the broiler industry and allowing companies to take advantage of resources not previously available. Utilizing brand names began, precipitating the vast number of chicken products are marketed under brand names today.

In the 1970's the broiler industry began the full transition into what it is today. Implementation of new technology, genetic improvement, production efficiencies, and automation allowed the industry to make the significant improvements. Technology and automation allowed the industry to begin offering consumers cut-up parts in the form of tray pack. By 1980, consumers started to change their product preferences, preferring more available cut-up and further-processed product options instead of the traditional whole or tray pack bird. Consumers wanted the bird to be broken down into more options for them to buy. It is during this time the industry gained a crucial insight about consumers -- they are willing to pay a premium for further-processed products, accelerating evolution of value-added businesses. The industry began to change and develop with technology allowing production efficiency gains to continue. Industry expansion in the 1990's, along with consumer's taste and preference changes transformed the broiler market to become even more intricate and developed.

Technological advancements allowed consumers to become increasingly aware about how and where their food was produced. In 1998, the USDA required Hazard Analysis and Critical Control Points[6] (HAACP) to be implemented within processing plants to increase food safety and quality (National Chicken Council, 2012). Over the past 15 years the broiler industry has become even more efficient, consolidated and expanded globally.

Economic Importance to the United States

The broiler industry is significant to the United States economy. In 2016 the industry provided nearly 1.2 million jobs, 68 billion dollars in wages, 313 billion dollars in economic activity and 24 billion dollars in government revenue (John Dunham & Associates, Inc., 2016). This assessment includes all job classifications that are tied to the industry in one-way or another. Sales totaled nearly 48 billion dollars in 2015. The broiler industry alone accounts for 60 percent of the 48 billion dollars (National Agricultural Statistics Service, 2016). Yearly production has increased to just surpass nearly 40 billion pounds produced in 2016 (National Chicken Council, 2017). "World meat consumption, according to OECD and FAO projections is expected to average 36.3 kg in retail weight by 2023, an increase of 2.4 kg as compared with 2013" (The Poultry Site, 2015). Approximately 72 percent of the overall meat consumption increase is estimated to come from an increase in poultry consumption.

The USDA Economic Research Service publishes a monthly report giving an outlook on the livestock, dairy, and poultry industries. In the April 2017 publication, it states "February broiler production and exports increased from last year, and higher-than-expected prices in late-March led to upward revisions for the price forecast" (Haley & Jones, 2017). Broiler exports for

[6] HACCP is a management system where food safety is addressed through the analysis and control of products in all forms from acquiring the product until final consumption by consumer (U.S. Food & Drug Administration, 2017).

2017 are up roughly 2 percent from 2016 with the driver being exports to South Africa; which, were up nearly 25 million pounds, which passes the recent record level.

Industry Evolution and Company Structure

In the early to mid-90s, a shift in company structure occurred such that individual contract production farms expanded and smaller farms slowly stopped production. The accelerated pace of vertical integration of the integrator companies led to increases in food safety and quality assurance, efficiencies, and cost reduction throughout the process. Vertical integration also resulted in a regional shift of production to the South and Midwest states. In 1995 approximately, 83 percent of farms producing poultry were in the Northeast, Appalachia, Southeast, Delta, and Corn Belt regions (Perry, Banker, & Green, 1999). Warmer parts of the country with easier access to water means lower expenses incurred by the grower. Vertical integration, larger farms and legal changes have all caused integrators to create contracts for the growers.

In the industry, today, the clear majority of individual broiler growers (over 95 percent) work with an integrator through independent contract arrangements. The contract system allows individual growers to have access to an outlet for their production outputs along with the technical guidance from experts in the industry. Contracts have since shaped how a grower enters the industry and receives compensation and provided guidance for production limitations, equipment and facilities upgrades and management responsibilities. Contracts formalize the entire production and processing interfaces and provide specific agreement parameters between the producers and the processors. In 1995 there were approximately 49,716 farms producing poultry or eggs which totaled 14.5 billion dollars -- nearly 17 percent of the total value of all livestock commodities produced (Perry, Banker, & Green, 1999).

"In 1980 the top 20 poultry companies processed 64 percent of broilers for the industry. Between 1990 and 2000, market share of the top three integrators jumped just over 5 percent from 35.47 percent to 40.50 percent. In 2000 the top 20 companies produced 86 percent of the broilers slaughtered" (WATT Poultry, 2001). In the early 2000's the following major acquisitions or agreements continued to change the industry:

Tyson Foods Inc. acquires IBP

ConAgra acquires Seaboard Corporation

Pilgrim's Pride acquires WLR, Inc.

Cargill acquires Agribrands

JBS acquires Pilgrim's Pride

Bachoco acquires OK Foods

Peterson Farms & Wayne Farms sign a managerial agreement, which formed the company now known as Crystal Lake Foods, LLC.

In a 2009 interview, WATT Poultry USA asked economist Dr. Paul Aho to describe the poultry company of 2017 and how it will be different from today (Thornton, 2009).

> I think there will be two kinds of poultry companies in the future. There will be a few very large companies of the type we see developing today and also a number of smaller players that may be very different from today's poultry companies. There will be three or four national companies that market coast to coast with a product line in every market Those companies will take 60 percent to 70 percent of the market There may also be a couple dozen-niche players with 30 percent to 40 percent of the market Those companies could be quite different from the poultry companies we've seen up till now. Some of them may not be completely vertically integrated; some of them will be selling very specific products only to very specific markets. Some of the most unusual changes will be coming about in those surviving niche players. The traditional, vertically integrated, full-product-line companies with only one plant may be on the way out. Replacing them will be companies of the same size but with niche products.

Today, broiler companies have shifted their focus to building longevity for the company. Some companies solely focus on producing broilers while others pursue a strategy of becoming global food providers. Product offerings now consist of a variety of portfolios. A few companies now produce other proteins (red meat) and alternative proteins (utilizing plants) as well as complementary bakery items. Having product variety allows companies to reach more consumers based on the companies' overall strategy. The multitude of different products allows companies to broaden their brand portfolio to customers. Consumers continue to drive the direction of change for producers. Today's integrators are balancing the consumer's fast-paced and life style integration approach in their product development. Consumers' ever-changing life styles shape the products that find their way into the market This constant change results in challenges processors currently face today, ranging from antibiotic use to animal welfare to nutritional labeling. These challenges have become a more prevalent topic as the industry expands globally.

Exports

In 1991, a government sponsorship between the United States and Soviet Union marked the beginning of exports for broiler leg quarters, with a vigorous trade with the Former Soviet Union, primarily Russia, continuing through the next decade. In 2001, U.S. poultry exports skyrocketed accounting for nearly 20 percent of U.S. production amounted to over 2 billion dollars (National Chicken Council, 2012). The United States is the second largest chicken meat exporter next to Brazil. The United States and Brazil accounted for approximately 76 percent of global exports of chicken by 2005. "In 2009 broiler exports went down 2 percent as Russian quotas limited access to the country's market (The Poultry Site, 2010)". As productivity in the U.S. agriculture industry continued to grow, it did so at a faster rate than domestic demand, prompting U.S. farmers and industries to rely heavily on export markets to keep prices at a sustainable market level (Economic Research Service, 2017).

Global exports are expected to increase nearly 4 percent in 2017 due to the expansion of the United States and Brazil shipments (Foreign Agricultural Service, 2017). The European Union will see their exports decline roughly 8 percent in 2017 due to highly pathogenic avian influenza (HPAI) trade restrictions (Foreign Agricultural Service, 2017). HPAI outbreaks in China make it difficult for producers to obtain the popular poultry genetic lines to produce broilers there. AI has a greater susceptibility with older chickens such as layers[7] and original genetic lines; therefore, AI outbreaks are causing China to increase their imports nearly 40 percent in 2017 (Foreign Agricultural Service, 2017).

The global broiler export market has dramatically evolved since its beginning in the early 90's due to efficiency, trade policies, population growth, relative price changes and exchange rates. Each of these factors are constantly changing, making the export market more complex. "U.S. broiler meat exports are projected to rise about 12 percent between 2013 and 2022" (Davis, Harvey, Zahniser, Gale, & Liefert, 2013). Export market destinations continue to expand globally. In 2012 the U.S. was exporting to approximately 150 countries. Technological advancements and new trading opportunities have allowed the United States to increase export market share. In 2017, the United States is forecasted to export approximately 16.9 percent of broiler production or nearly 7 billion pounds (National Chicken Council, 2017). World markets, economic growth, exchange rates, income, prices and governmental policies constantly affect the United States and overall world trade (Economic Research Service, 2017).

[7] Layer hens are kept for egg production. These birds are kept for approximately 2 to 3 laying cycles that consist of 60 to 65 weeks each (Clauer, 2017).

Global Influences

The industry continues to expand as producers provide more food for the ever-growing population. The exponential growth of global population means more food is needed. Chicken is one of the few proteins globally accepted regardless of religion, availability and purchase cost. A global presence for integrators means they must continually formulate new strategies. Genetic companies have started to strategically place primary genetic lines in countries outside their home bases (U.S., EU). One of the key parts of the overall pipeline is pedigree stock. Parent pedigree stock[8] is the beginning of the genetic pipeline; one female will produce approximately three million market broilers. Top broiler breeding companies have spread across different parts of the globe. This strategic move will help manage the threat of avian influenza (AI) outbreaks. Strategic placement helps to ensure the least, overall effect when a disease outbreak happens. Based on the severity of an AI outbreak, countries can enact import bans. AI results in not only trade bans but also affects production efforts. China is currently battling multiple strains of AI, resulting in increased imports (Foreign Agricultural Service, 2017).

Global broiler consumption is rising and forecasted to increase 1.6 percent year over year from 2013 to 2022 (The Poultry Site, 2014). Production of broiler meat will continue to increase; the FAO suggests all meat, including red, meat will increase to 57.7 million metric tons in 2023. Broiler production will account for nearly 28.3 million metric tons of the overall increase (WATT Global Media, 2015). Production will increase in regions of low-cost and slow in those of high-costs. There is on average enough chickens in the world for three per person at any given time (The Economist Online, 2009). Broiler meat has become a more available global protein

[8] Pedigree stock are the primary and elite foundation, then great-grandparent, and grandparent birds. Grandparent flocks produce the final generation of breeding birds consisting of parent stock. Eggs from the parent stock hatch to become production birds for human consumption.

due to the industry's expansion. By 2020, Africa will experience a population growth of nearly 25 percent (Davis, 2015). This population growth will result in increased broiler consumption resulting in industry growth in the region. Poultry's global presence allows it to continue to be the top animal protein exchanged globally (Davis, 2015).

Exogenous Factors Influencing the Broiler Industry in the United States

Annual broiler production increased to just over 40 billion pounds produced in 2016 (National Chicken Council, 2017). "World per capita meat consumption, according to OECD and FAO projections is expected to average 36.3 kg in retail weight by 2023, an increase of 2.4 kg as compared with 2013" (The Poultry Site, 2015). With this increase in overall meat consumption, approximately 72 percent of the increase is estimated to come from broiler consumption.

To fully understand the dynamic nature of the broiler industry, it is important to identify relevant exogenous factors. The primary factors that have affected the industry structure, profitability, and supply and demand include diseases, recession, and drought. Each of these factors create different kinds of shocks which, affect the pricing of wholesale broiler parts. Each will also cause different supply and demand shocks within the industry. The following three sections give a brief overview of the effect each of these factors has had and delineate important time periods when they have taken place. Each factor may cause a different price reaction. Disease outbreaks and droughts tend to increase prices; however, with a recession prices may well decrease due to lower disposable incomes available for value-added products. These considerations help provide an understanding of how prices have been affected (Figures 1 and 2). It is important to note this research focuses on technical aspects of price forecasting and not the fundamental aspects. The above factors are fundamental but worth noting as a foundation and understanding for price movement as a basis for the technical forecasting that comprises this thesis.

Disease Impacts

AI is a zoonotic disease to which domestic poultry are highly susceptible. AI is a naturally occurring virus in waterfowl, carried by migratory birds through their migratory pathways (CDC - Centers for Disease Control and Prevention, 2017). The virus sheds and can infect the broiler or broiler breeder and become either low pathogenic avian influenza (LPAI) or (HPAI). LPAI can cause decreases in weight gain and feed consumption. However, HPAI is much more extreme, causing mortality at 90 to 100 percent within 48 hours (CDC - Centers for Disease Control and Prevention, 2017). Once an ‘outbreak’ occurs, the poultry supply pipeline may be affected by quarantine, disposal or trade embargo. The resultant economic effects begin and can be serious to different degrees dependent upon whether the affected flocks are parent breeder stock or primary breeders.

At the turn of the 21^{st} century, United States poultry exports jumped nearly 3 percent from 15.6 percent in 1999 to 18.0 percent in 2001 of total production; since that time, exports have fluctuated between 14 and 20 percent (National Chicken Council, 2017). During the beginning of 2015 there were over 150 confirmed cases of AI in backyard and commercial broiler and turkey flocks, impacting primarily the Upper Midwest and Western Corn Belt. An emergency economic impact analysis from the University of Minnesota Extension estimated approximately 309.9 million dollar impact in the Greater Minnesota area alone (Darke County Extension, 2015). Analysts estimated a ripple effect of approximately 1.8 million dollars in overall economic losses for each 1 million dollars in direct losses.

Due to the outbreaks, between January and April 2016, there was a 13 percent decline in poultry exports to partners with a trade ban as compared to the same time a year previously. Disease outbreaks cause a major impact on the global supply of poultry products. In 2017, global exports are forecasted to increase 4 percent from 2016, with most coming from Brazil due to the AI outbreaks in the United States. Thus, Brazil's total share of export volume is expected to grow by approximately 10 percent, while the United States' share of export volume is expected to grow by 4 percent (Foreign Agricultural Service, 2017).

Recession

Throughout the Great Recession, which began in December 2007 and ended in June of 2009, consumer's spending habits changed on how and where they spent discretionary income. During the tougher economic conditions consumers also ate out less; when they did eat out it was at cheaper locations (Reed & Crawford, 2014). During this period, total meat consumption dropped by approximately 9 percent; poultry accounted for nearly 6 percent of the decline (The Poultry Site, 2015). During this time, poultry companies began to alter focus on their product portfolio mix. They responded by enhancing their further processed value-added product offerings in retail and food service operations to account for volume that shifted to lower margin, lower service outlets. The recession was a hard time for consumers and integrators, and coincided with a period of high grain prices, which increased feed costs. Normally, during recessionary times there is a decrease in red meat consumption and an increase or at least maintained poultry consumption. However, during the period of high feed costs, there was a *per capita* decline of 2 pounds in annual poultry consumption. The only other time this happened was in the early 70's with the combination of the oil embargo, recession, and grain crisis (Aho, 2011).

During the Great Recession, 73 percent of consumers looked for alternative, cheaper cuts of meat (North American Meat Institute, 2010). Consumers had budget to afford protein but sought cuts they were not used to purchasing but were cheaper. The recession also led to a decline in agricultural exports and prices for U.S. produced commodities.

Drought

In addition to the negative impacts of the recession, weather-related disasters affected the poultry industry. For integrators, the exogenous costs of growing birds would typically affect the supply. Whole grains such as corn, barley, sorghum and wheat are extremely important to poultry diets. In 2009-2010 broiler production declined slightly while adjusting to rising feed costs; however, future projections point to increases in broiler production over the next few years (Economic Research Service, 2009). In the broader livestock industry, feed costs account for 50 to 60 percent of operating expenses; feed runs as much as 70 percent for broilers. Rising feed costs tighten integrators' profits. Such increase disproportionately affect other proteins, leaving poultry prices lower than red meat.

In the summer of 2012, drastic weather conditions caused the most severe drought the United States had experienced since the 1950's (Adonizio, Kook, & Royales, 2012). Drought caused corn prices to increase over 120 percent causing export prices to hit record levels. The United States is the world's largest exporter of corn. A major drop in corn production decreased global supply and raised prices.

"The government's forecast, based on consumer price index for food, estimated prices would rise 4 to 5 percent for beef in 2013 with slightly lower increases for pork, eggs, and dairy products" (Lowrey & Nixon, 2012). Bill Roegnik, National Chicken Council, told Congress in 2014 "the chicken industry is one drought away from another economic crisis due to the corn supply volatility" (Johnston, 2014). Crop price volatility plays a crucial role for the poultry industry, which is why crop supply and demand play a key role in the broiler pricing strategy.

Market Structure

Food producers are now being challenged by the food retail operators to be more efficient, reduce food costs, and create new products through innovation as a result of increasing consumer pressure. Consumers drive the market based on their buying decisions and consumer preferences have been changing. Consumers in the United States only spend approximately 6.4 percent of their household income on food (Gray, 2016) and in 2015; approximately 34.4 cents of every dollar consumers spent went to foodservice establishments (Economic Research Service, 2017). Currently the United States does not import any poultry products; this is attributed to the comparative advantage generated by production technology (Poultry Technology Center).

Consumption of broiler meat is on the rise globally, but is affected by the income status of households and prices and availability of other competitive proteins. "Among low-income household's dark meat, such as chicken leg quarters, is preferred. Consequently, the higher value cuts and added-value items are mainly purchased by the middle and high-income groups" (The Poultry Site, 2014). If poultry remains relatively inexpensive, its consumption will continue to rise—particularly in developing countries. Product development for integrators has been crucial to expanding their offerings to consumers. Since 2000, consumers have preferred products that are value-added and further processed. Some companies have shifted to become diversified food production companies rather than only broiler companies. A survey by National Chicken Council revealed 65 percent of consumers bought packaged boneless skinless breasts in 2003 and 30 percent purchased bone-in chicken (Benwick, 2004).

Food Safety and Awareness

Production and processing advancements in the broiler industry have led companies to drive innovation through new product creation. In 1949, the USDA started a voluntary program of grading broiler to assure consumers of high-quality products (National Chicken Council, 2012). The first HACCP program was instituted when Pillsbury Company created products for NASA. In 1971, Pillsbury presented the HACCP concept to the FDA at a national conference. The FDA started to slowly implement parts of the HACCP program to low acid food regulations in 1974. During the 70's *Clostridium Botulinum* poisoning broke out in commercially canned food; from that outbreak FDA implemented HACCP in large food processing companies. In the mid 80's to early 90's, HACCP programs took full effect in food processing industry and governmental agencies (Surak, 2009). Since the turn of the millennium, HACCP programs have grown and are ubiquitous throughout all the food industry. "In the future, we expect to see further improvement that will allow the U.S. food processing industry to deliver safe food products to their consumers anywhere in the global market place" (Surak, 2009).

In the early 2000's, integrators realized consumers demanded more information about their food products. Label Insight performed a study, which "reported 94 percent of respondents said companies providing product information on their labels not only matters, but also impacts their buying decisions" (Business & Politics Staff, 2016). These changes have fostered the 'transparency movement'. As companies create new products, they are doing so with the focus of the food processors' end consumer, creating different products based on consumer desires.

Integrator Quality Standards

In the beginning of broiler production, processing inspection was voluntary. In 1959 federal inspection by the USDA became mandatory. In late January of 1998, USDA implemented and required Hazard Analysis and Critical Control Points, "HAACP", to strengthen quality control within processing plants (National Chicken Council, 2012). HAACP plans are put in place to identify critical points during processing at which physical, chemical, or microbiological hazards might be of concern. These measures were put in place to strengthen and make the food supply safer for consumers.

Most notable advancement from the broiler industry was introduction of product specifications (specs). As advancements within the industry were made around product production, it became apparent, product specification sheets were needed. Product specs outline all the ingredients, individual products, weight and size limitations, microbial testing counts, shipping information and handling directions (Amsbary, 2013). This ensures the foodservice food retail operator all products will be consistent to set the cooking time to reach the optimal cook and temperature. Product specs for all products help ensure the final product the food retail operator or consumer receives is consistent, high quality, and safe. Product specs are constantly reviewed as technology improves, processes become more efficient and food safety is evaluated. With all the products on the market, it is important to have documentation to create a standard of identity as well. Standard of identity helps to hold an integrator to accountable for which a product will be delivered upon.

Product Differentiation

At the beginning of the commercial broiler industry, only whole birds were sold, as New York dressed having only the feathers and blood removed. In 1942 a processing plant in Illinois was the first to gain governmental approval of "on-line" evisceration. As the industry began to increase technology usage to create the automated production process in place today, processors could increase line speed, product efficiencies, and complexity of packaged products. Plants now do bone-in and boneless cuts, as well as further processed and value added. Choices consumers make are based on income, diet, health attributes, accessibility and availability within market are the driver behind these changes.

Integrators have a difficult task of growing a broiler that will have the specific physical attributes—length, width, and depth of cuts, and small or big birds. Broiler genetic research companies are working on today will not get into the broiler market for another five years. Thus, companies are constantly on the forward-looking front for what consumers will want. Since vertical integration became prominent, the broiler chicken has changed dramatically, increasing in weight and feed efficiency, making today's broiler a better value than those of the past.

Boneless, skinless, chicken breasts (BSCB) became larger over the years. In 1980 each lobe of the BSCB weight approximately 4 ounces; now they are closer to 5.25 ounces (Benwick, The Odd Thing About Chicken Breasts, 2004). To combat the increase in pack weight and thus cost to the consumer, the integrators worked to create a new cut. Perdue was the first producer to do this; they sliced the BSCB to $^{1}/_{2}$ or $^{5}/_{8}$ inch thick to create a BSCB cutlet (Benwick, 2004). Cutlets are just one of the many new offerings of value added products consumers can now purchase due to technological advancements.

Technological advancements have allowed the broiler industry to take traditional cuts of meat and cut or portion them literally into almost any desired size or shape. Design Systems Inc. (DSI) waterjet portioning system is a prime example of a machine that can take the normal breast and perfectly portion it. The DSI scans the individual breast to determine the most efficient cuts and makes each individual cut as valuable as possible (John Bean Technologies Corporation, n.d.). Advancements have allowed the industry to make products for new markets that integrators were not previously in. Today integrators have two major sectors they produce for—foodservice and retail. Foodservice consists of: national account chains (McDonalds, Taco Bell, Sonic, Hardees and Burger King), K-12, government and convenient stores. Retail consists of companies such as: Wal-Mart, Kroger, SAM's, Costco, Aldi, Hyvee, Target, etc.

Market Make-Up; Retail and Foodservice

In the early 70's broiler companies began to truly focus on mass marketing their products using commercials and print media. Consumers became more exposed to different brands companies had to offer. Most if not all chicken at retail grocers carries a brand name from either the producer or the grocer. "Store brand products were 31 percent cheaper across product categories than their national brand counterpart" (Narula & Conroy, 2010). Consumers rely on brand names they trust and know are reliable.

The retail sector continues to grow; in 2011 the industry was valued at approximately 571 billion dollars (Elitzak, 2016). Grocery stores accounted for nearly 91 percent of the overall retail sales. Nearly 20 large food retailers made up the approximately 450 billion dollars in the industry for 2013. They account for 63 percent of U.S. grocery store sales, which is a 39.9 percent increase since 1993 (Elitzak, 2016). Over the years, the retail industry has changed and added bulk purchasing in the form of club stores to force tighter margins on producers and lower prices for consumers. Two of the market leaders, Sam's Club and Costco, both opened in 1983 with a few months separating the two events. These two companies were—and still are—on the forefront of bulk packed items for consumers.

Much like retail, the foodservice market is rapidly growing. In 2010 the approximate size of the foodservice industry was estimated at about 594 billion dollars (Elitzak, 2016). By the end of 2015, the industry closed with approximately 761 billion in sales (Carbonara, 2015). More consumers are purchasing food away from home at foodservice establishments. To help the food retail operators increase customer traffic to drive sales, the focus shifted to locate more food retail operators closer to consumers' homes and work places to make it easier for food retail operators to gain access (Elitzak, 2016). "Technomic's Digital Resource Library has shown chicken brands are some of the fastest-growing limited service food chains" (The Poultry Site, 2016). The driver behind this growth is business expansion, fresher product, and new, innovative menu options for restaurants.

Rotisserie Chicken – Growth in Deli Foods

Classic rotisserie chicken, a familiar dinner staple in many households, has also evolved over the years. Industry advancements have made the chicken presence within the deli and cold grab-and-go section to be more convenient and available to consumers. In 2010, approximately 600 million rotisserie chickens were sold in supermarkets, club store, and retail outlets. "An additional 200 million were sold through alternative foodservice outlets" (Benwick, 2012). The classic rotisserie chicken concept of a one-night family meal has changed with not only household size and bird size, but also with culinary preferences at the household level.

Rotisserie broiler packaging has also evolved, becoming more environmentally friendly, microwavable and oven safe, often with small handles to make carrying more convenient. Flavor offerings have expanded to include; Italian, lemon-pepper, maple, BBQ and many more. Production efficiencies have allowed the rotisserie chicken price to be affordable and comparatively very hard to bypass. "Rotisserie chicken is typically less expensive than uncooked alternatives" (Horizonweb, 2016). In 2011 Costco alone moved nearly 50 million rotisserie chickens across the scanner at the register (Benwick, 2012). Rotisserie chicken alone has market share of 43.7 percent of the total prepared chicken sales in the United States. (Statista, 2016). According to Technomic data, rotisserie chicken has appeared on 6 percent more menus in 2015 than in 2013 (Horizonweb, 2016). Growth in the market is attributed to consumer's fast paced lifestyles that have them on the go constantly. Rotisserie chicken is just one of the many examples of chicken offerings which have expanded with growth and opportunity over the years.

Next Gen Retail Store – Dry Goods Shrink, While Deli and Perimeter Expands

Retail stores today are shifting their focus on how they attract consumers. Retailers must adapt to the consumers' rise in on-line ordering that accommodates fast-paced lifestyles. Focus is moving toward expanded product offerings, smaller brick-and-mortar and more online presence (International Dairy Deli Bakery Association, 2016). Foodservice innovation will drive growth for the convenience stores (C-stores) segments. C-stores will change design and environment within stores based on customer demographics. Dollar General announced in March of 2017 a company wide effort to bring fresh produce to more stores. Efforts are to focus on challenging their competitors (Wal-Mart) to retain customer basis and attempt to attract new customers with a new company strategy (Gustafson, 2017). Consumers are shifting their purchasing habits and strategy, making more frequent trips to the store for fresh and prepared foods. "Consumer Reports estimates that prepared meals purchased from grocery stores are nearly 29 billion dollar-a-year business" (Chute Gerdeman, 2017).

Millennia's are the drivers behind this change. Younger generations want healthy, local, organic, prepared, and less processed food options when shopping. Millennia's have an 'in the moment' mentality with their fast-paced lifestyles. This is where prepared foods, the deli cold and hot grab-and-go section, and fresh sections have seen growth. Consumers are becoming more and more confident with purchasing their dry staples online and having delivered to home or ready for in-store pick up. Retailers are changing their internal landscape, by adding full-service restaurants, hot bars for food, and chef inspired meal solutions to name a few (Berry, 2015). Focus and expansion will likely allow broilers producers to expand their product offerings and capture more market share with consumers. Costs will be a major influence on how the industry adapts and changes to better serve the food retail operators and final consumers.

Theory and Technical Estimation Procedures

The objective of this research is to specify and estimate a model to predict the prices of wholesale broilers parts which include; drumstick (DRUM), jumbo boneless skinless breast tender out (BSBTO), leg quarter (LQ), thigh (THIGH), small wing (SMWING), jumbo wing (JMWING), tender (TENDER) and whole bird without giblets weighing 2 ¼ lbs. (WOG). The purpose of this is to generate a better understanding of parts prices interactions to allow more insight for the industry on price forecasting. Allowing producers to better strategize when negotiating contracts with food food retail operators.

In econometrics determining the preferred modeling approach is not a precise procedure. For several reasons, not the least of which is the number of potential modeling techniques may be available and appropriate to varying degrees. Building the most useful model is crucial to the broiler industry. However, most models are complex and each comes with its own deficiencies and challenges. Modeling the broiler industry makes this process even more complex with the extensive amount of possible exogenous variables to choose for inclusion. Identifying the goal of the economic model can facilitate model selection. Relying on previous investigations into chicken price prediction (McKenzie and Goodwin), our goal is to decide between a univariate autoregressive (AR) model for each of the eight prices and a vector autoregression (VAR) model estimates all five equations simultaneously. Both AR and VAR models require empirical decisions that need to be made about model structure. The number of lags to include, the sample period from which to base the model on and the variables to include are all major concerns when estimating both AR and VAR models.

Setting the sample size is crucial for AR and VAR models to ensure a large enough training set is available. A training set allows the model to 'understand' how the variables interact with one another. Training set builds the forecasting power of the model. A robust sample should include price ups and downs is especially important for AR and VAR models. Extreme outlier observations in the sample can cause the forecast to be less accurate and have large forecast errors. AR models were utilized in the econometrics literature prior to VAR modeling being developed. VAR models might analyze volatility better due to providing a causal and feedback relationship of the other variables nested within the model. The VAR technique utilizes nesting of AR models to potentially create a more robust model. Chris Sims introduced VAR in 1980, where he demonstrated VARs provide a flexible framework for analyzing economic time series. VAR modeling is an approach that builds on the causal and feedback relationships of the model's variables. VARs analyze the interaction between all variables that are included for analysis. VAR modeling allows more complex relationships and interactions between the all the variables included in the model.

Due to the multitude of inputs in producing poultry, it is important to know which ones to include in the models. VAR modeling techniques have been widely utilized in other research areas including oil, gas and realty. The following discussion will give an alternate look into other industries where price forecasting using VAR has been applied. Bessler et al., utilized VAR modeling to understand price interaction of corn price, poultry price and retail poultry prices. Two different time periods were analyzed: 1956 through 1968 and 1973 through 1985. Time split was determined because a few issues arose focusing on prices and wages such as:

termination of the Nixon Administration's wage and price controls preceding the first OPEC oil price shock; and restaurant industry beginning of marketing poultry. They performed shocks on the models to understand the dynamic attributes. Bessler et al., found differences between the two time periods. "Their results failed to reject their hypotheses about the differences; that the changes were demand-driven due to demand and preference changes at the retail level; and changes were due to technological changes which altered the dynamic relationships among corn and broilers prices" (Babula, Bessler, & Schluter, 1991). Findings were conclusive that industry structural changes within the corn market moving from many smaller firms to larger ones impacted the timing of shocks in the market Now corn price shocks happen sooner where "large producer-contracting processors now exhibit more price-making power (Babula, Bessler, & Schluter, 1991)." Due to vertical integration, larger processors are able to "pass rises in corn-based feed costs on to consumers in a more direct and immediate manner than in the earlier period (Babula, Bessler, & Schluter, 1991)."

Bessler et al., compared VAR modeling to the univariate ARIMA process (which can be very similar to an AR model) and found the univariate model to outperform their VAR model. This finding is important to note because a simpler modeling approach sometimes outperforms more complex models. Due to a less restricted parameter space, we would reason multivariate models should perform as well as or better than univariate models. However, it is not always the case depending on the system of equation(s) and variables included for the modeling purpose. Bessler et al., stated further research over different time periods or alternate commodities could alter findings. Choice of variables included in modeling is important. "Apparently, the instability of hog prices is not well accounted for by variables in the VAR model, since no improvement in forecasting ability is evident (Bessler & Brandt, 1984)." Nerlove, Grether, and Carvalho found similar results when forecasting prices for the cattle industry. Their indicators of fit strongly supported the univariate (AR) modeling approach over the multivariate (VAR) approach.

Bessler et al., utilize the VAR modeling technique in combination with Forecast Error Variance Decompositions (FEVD) and directed, acyclical graphs. FEVD "is the percentage of the variance of the error made." FEVD was used to quantify the importance of each shock in explaining the variation. Directed acyclic graphs (DAG's) provide information of causality among variables. Bessler et al., structure their VAR model with; time trend, season binary variables and event specific variables. Structuring in this way allows the model to react and handle time frames when certain events happened that do not normally occur. Analysis of the FEVDs allowed price forecasting into a longer horizon. Showing FEVDs have "important effects on the downstream markets over the longer horizons beyond the crop cycle. Doing this gave insight into the dynamic nature and quarterly responses of the VAR model's endogenous variables (Babula, Bessler, & Payne, 2004). They concluded from the research that time horizons extending beyond a single market year or crop year would allow ample time for necessary market shocks to take effect.

McKenzie et al., promoted utilizing a VAR modeling approach as an alternative price forecast for wholesale broiler parts to AR. VAR in combination with Forecast Error Variance Decompositions (FEVD) modeling approach was shown to be superior to the traditional Granger Causality approach. The forecast approach included the four main parts of the bird that are sold wholesale. When comparing the out-of-sample forecast between Granger Causality and Sims-Bernanke, the modeling techniques were consistent with one another. Granger Causality model requires many observations to choose between large groups of variables and select the required variables independent of forecast horizon. Findings resulted in the assumption that Sims-

Bernanke FEVD model selections would lead to better forecasting models than Granger Causality tests (McKenzie, Goodwin Jr. , & Carreira, 2007).

Alquist et al., analyzes multiple forecasting methods. Two of the model structures analyzed are AR and VAR. Utilizing an unrestricted VAR to start provides a foundation to building the VAR model. Unrestricted VARs utilize all variables in the equations, whereas a restricted one might include only some variables from multiple equations. The success of the forecasting power and accuracy is dependent on the choice of variables. Alquist et al., simultaneously explored the appropriate number of lags which should be included. The purpose of the lag exploration was to determine price forecast sensitivity. For oil pricing, it was determined that comparing lags of 12 and 24 months' lags typically produced a weaker forecast. Forecast accuracy diminished after 6 lagged periods. There was also discussion of selecting the proper sample period. When choosing the sample period, it is important that it is structurally equivalent to the anticipated structure in the forecast periods. It is crucial to have enough observations; however, it is also possible to have so many observations the forecasting power is compromised. Kilian and Murphy concluded for the oil industry it is important to include inventory shocks in the model as well when price forecasting. Traders base their buying and selling off the inventory of the market, expecting to buy at a low price when inventory is high and sell high when inventory is low. They concluded "proposing a dynamic simultaneous equation model including oil inventories that allows the identification of all three types of shocks" (Kilian & Murphy, 2010).

"VAR models have increasingly been used in macroeconomic research over the last decade or so, especially in the United States" (Robinson, 1998). VAR model specification requires identifying the proper number of variables and lags, which could lead to overparameterization. After comparing multiple models, Robinson found "VAR models are suited for short-term forecasting" (Robinson, 1998). Robinson found other models are highly unstable for short-term forecasting. Forecasting further out would require the use of models such incorporate an error correction mechanism. When compared with the other models analyzed; VAR had the lowest mean square error for predictions.

Pricing in the broiler industry is similar to in the oil industry. Analogous to oil pricing, broilers parts pricing is derived from the whole bird without giblets (WOG). The WOG provides a base price from which the individual parts are based and then the value from further production is added to arrive at a final cost. This research provides a better understanding of variable interactions along with determining the appropriate modeling technique for economists to forecast broilers parts prices.

Section III – Data and Methods

Regression Analysis of Time Series (RATS) software was utilized to perform all forecasts and model estimates. RATS is a comprehensive econometrics and time series analysis software package. To achieve objectives 1-4 the following techniques will be utilized:

1. *Find the best variable combination in a VAR model to identify which parts impact/drive price for other parts.*
2. Is the breast still the driver based on research by McKenzie et al.? Has the industry shifted to another part, i.e. wings since they are most preferred within food service establishments? A Diebold-Mariano test is used to compare forecast performance. After generating the forecasts from both models, the series of the differences between the two modeling methods will be analyzed.

3. *Use in-sample data to estimate models and out-of-sample observations to test comparative forecast accuracy.*
4. This allows comparing the forecasting power of each AR and VAR model estimated.
5. *Identify the best variable combinations for the AR and VAR models*.
6. A total of four different model specifications will be utilized. A) All eight parts. B) Front parts without the WOG[9]. C) Front parts with the WOG. D) Parts from the original model estimated by McKenzie et al., The front half of the bird was analyzed and not the back due to consumer preference as well as price volatility. Dark meat products are primarily exported to other countries because very little is consumed in the United States. White meat portions are highly sought by food service and retail providers. Justification behind with and without the WOG is to determine if the whole bird in its original state has any interaction with the individual parts prices.

Data

Data for this project utilized Urner Barry (UB) average monthly reported prices for wholesale chicken and chicken parts. UB is considered an unbiased reporting firm that gives pricing data for poultry, red meat, egg, and seafood related segments to the food industry. UB is regarded as a trustworthy source for buyers and sellers to obtain accurate and timely price information. Each opening day, experienced marketers at UB collect information from buyers, sellers, and brokers to report real time prices. The constant interactions with the individuals allow the UB personnel to adjust prices. It also allows them to see the potential direction the market could move. Data collected from UB includes: products being traded, products producers

[9] Whole bird, without giblets, that includes the whole breast, two wings and two legs. The head, feet, and internal organs are removed.

are selling, bid and sell prices, and other information to make informed decisions as determined by UB. Prices reported by UB used in this study are the average monthly prices and do not represent the high or low sales or bids.

Monthly prices were collected from January 1989 through May 2017. The specific parts prices collected are: drumstick (DRUM), jumbo boneless skinless breast tender out (BSBTO), leg quarter (LQ), thigh (THIGH), small wing (SMWING), jumbo wing (JMWING), tender (TENDER) and whole bird without giblets weighing 2 ¼ lbs. (WOG)[10]. These are the main parts sold wholesale to retailers and foodservice establishments. Producers use these parts to make further processed value added products.

These eight parts are all sold on the wholesale market, which facilitates accurate price reporting. Descriptive statistics of prices of these parts are reported below in cents per pound in table 1. Table 1 contains descriptive statistics from the time period that McKenzie et al., analyzed of January 1998 plus the inclusion of additional parts. In table 2, the extended time period beginning where the data ended from McKenzie et al., running from August 2007 through May 2017 is shown. Variances are higher in period 2 except for parts BSBTO and TENDER where they are higher in period 1. Volatility is relatively higher in period 2 than in period 1. Means are higher in period 2 than in period 1[11]. BSBTO and DRUM have a higher max price in the first period, all other parts are higher in the second period. The DRUM is only higher by two thousandths of a cent. The above comparisons are magnitudinal and were not tested for statistically significant differences, as they are included for perspective.

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[10] Prior to 1998, wings were in a single category. However, in 1998 the industry began to market and price wings based on their size. Because of this, UB began tracking prices both small and jumbo wing prices.

[11] All prices analyzed are nominal.

Figures 1 and 2 plot each broiler part price for all the observations used in this study period 1998 through 2017. Prices for the Northeast region of the US were reported the data source; a US price was not available. The time periods are partitioned for the base data sued by McKenzie et al., 1998-2007 (figure 1) and the data post McKenzie et al., 2007-2017 (figure 2). In figure 1 there are three major groupings of the parts with respect to their volatility. TENDER and BSBTO exhibit the most price volatility, particularly when comparing prices from 2002 to 2004 when they almost doubled. SMWING, JMWING and WOG experience small price fluctuations. However, at the points they do display volatility is where supply shocks to the market occurred due to an AI outbreak or drought with high feed prices. THIGH, DRUM and LQ are at the bottom of the figure with the lowest prices. The THIGH, DRUM, and LQ (which are primarily exported) exhibit price increases in 2005 from the AI outbreak in 2004. The export market prices are lagged from the domestic prices due to export contracts and movement of product. Exported parts have a different selling period due to cold storage and handling regulations, which must be followed. The back half of the bird is primarily exported, integrators do very little value adding where extra costs are applied to the final product.

Table 1

Descriptive Statistics of Monthly Average Prices (Cents/Pound) Selected Broiler Parts for the Northeast U.S. Market (January 1998 - July 2007)

Part	Mean	Variance	Minimum	Maximum
BSBTO	149.17	843.74	105.00	255.55
LQ	26.33	71.68	13.76	48.81
SMWING	80.65	587.08	41.00	136.00
JMWING	81.16	402.04	42.63	122.00
WOG	64.05	97.05	46.59	90.00
THIGH	30.37	103.63	14.67	58.29
TENDER	145.08	1098.95	91.40	235.00
DRUM	33.90	81.06	20.42	65.29

Table 2

Descriptive Statistics of Monthly Average Prices (Cents/Pound) Selected Broiler Parts for the Northeast U.S. Market
(August 2007 - May 2017)

Part	Mean	Variance	Minimum	Maximum
BSBTO	141.56	468.83	106.00	206.00
LQ	40.37	75.87	21.00	54.00
SMWING	139.32	933.83	75.62	196.27
JMWING	133.46	975.65	67.45	188.78
WOG	94.19	167.44	71.61	126.33
THIGH	55.48	146.96	28.00	74.00
TENDER	154.79	856.71	101.16	236.00
DRUM	48.16	130.87	21.00	65.00

This reflects the weak demand for dark meat products meaning supply in cold storage[12] increase but not indefinitely. With demand being low and supply increasing prices for dark meat items remain relatively low.

Figure 2 uses observations from September 2007 through May 2017. This interval experienced drastic volatility: recession, drought and extreme outbreaks of AI which all affect industry pricing. During this time the part's prices began to exhibit movement independently of each other rather than as a group. The most notable event was the AI outbreak in 2014, which caused prices to increase. AI caused a supply shock domestically and in export markets due to the number of birds euthanized. In contrast to figure 1, figure 2 shows the parts starting to move away from their earlier groupings. This change is likely driven by consumer demand changes in lifestyles and preferences. Prices of the back half of the bird (LQ, THIGH and DRUM) all remain relatively grouped together with little volatility. Front half parts (TENDER, SMWING, JMWING and BSBTO) began to exhibit their own identity moving away from the previous groupings. We can see the wing markets began to take form along with the tender where their pricing shows no relation to the other parts. Previous research shows prior to September 2007, the boneless skinless breast was the main determinant of all other price shocks induced to other parts. Consumer preference shifts are likely causing changes in the market due to more interest from consumers in wing products. When an exogenous shock to the industry does occur such as the AI disease outbreak in 2014, all parts experience price fluctuation to some extent. One of the most notable observations from looking at the two figures is when there is price increases; they decrease rapidly to where they were trending before.

[12] Survey conducted by USDA NASS that inquire about cold storage products that are located across the United States. This gives the industry a gauge of the current supply available to consumers. The understanding of the supply and demand drives the final prices.

Methods and Equations

For this project, multiple samples were selected: 1) the original time frame of January 1989 through May 2017 and 2) January of 1998 through May 2017. The first sample uses the original parts (BSBTO, WOG, LQ and WING) with additional observations. In-sample selection is from January 1989 through January of 2000 with the remaining being out-of-sample. The second sample uses additional new parts (SMWING, JMWING, TENDER, DRUM, and THIGH) and the time frame 1998 through 2017. In-sample was January of 1998 through August of 2007 with the later observations being out-of-sample. Each of the exogenous factors discussed in the literature review play a vital role in determining the most effective timeframe choice. The out-of-sample period captures the following major effects on pricing: recession from 2007-2009, extreme drought in 2012, and multiple disease outbreaks[13] most notably in 2015.A dynamic estimation method is implemented. Consider the second sample. VAR and AR models are initially estimated using observations from January 1989 through August 2007. Forecasts are made from these models for the next nine months, September 2007 through May 2008. Then September 2007 observations are added to the estimation sample and the models are re-estimated. Forecasts are made for the next nine months (October 2007 through June 2008). These iterations continue until a forecast is made for May 2017.

[13] 2008 outbreak in China and countries in Asia, 2009 in Egypt, 2010 in Japan, 2012 in China and the United States in 2014 (World Health Organization, 2012)

Figure 1

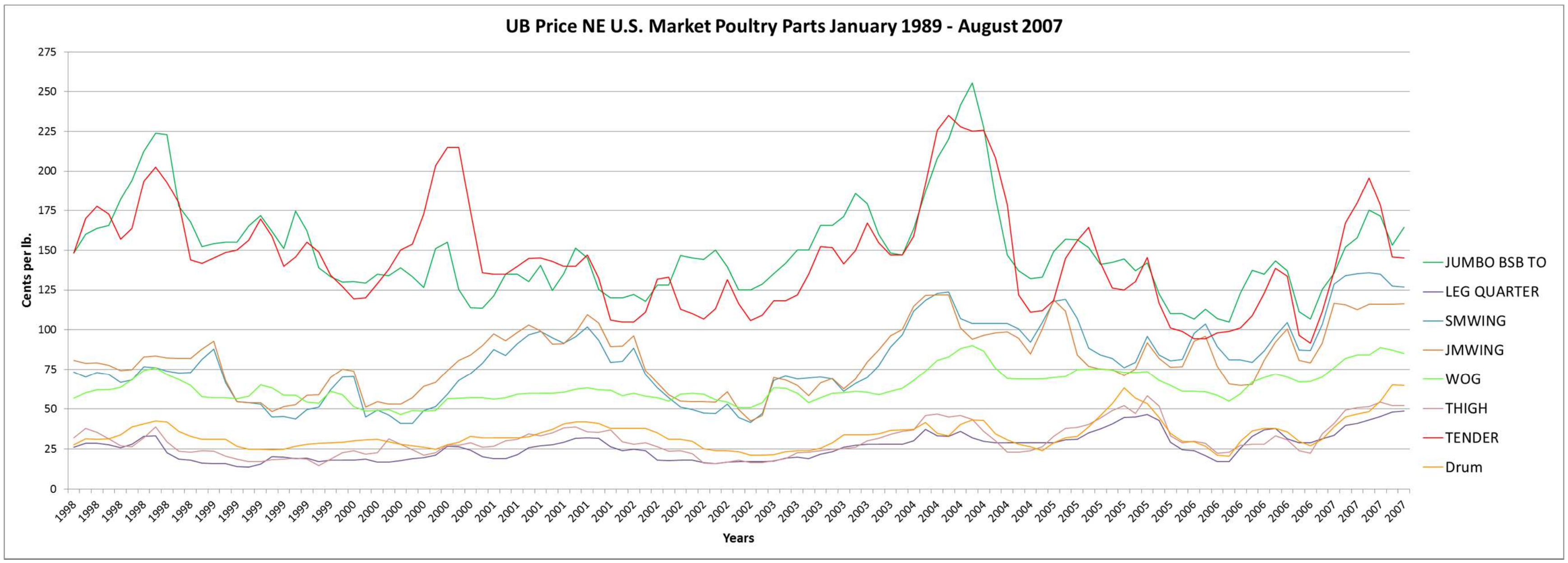
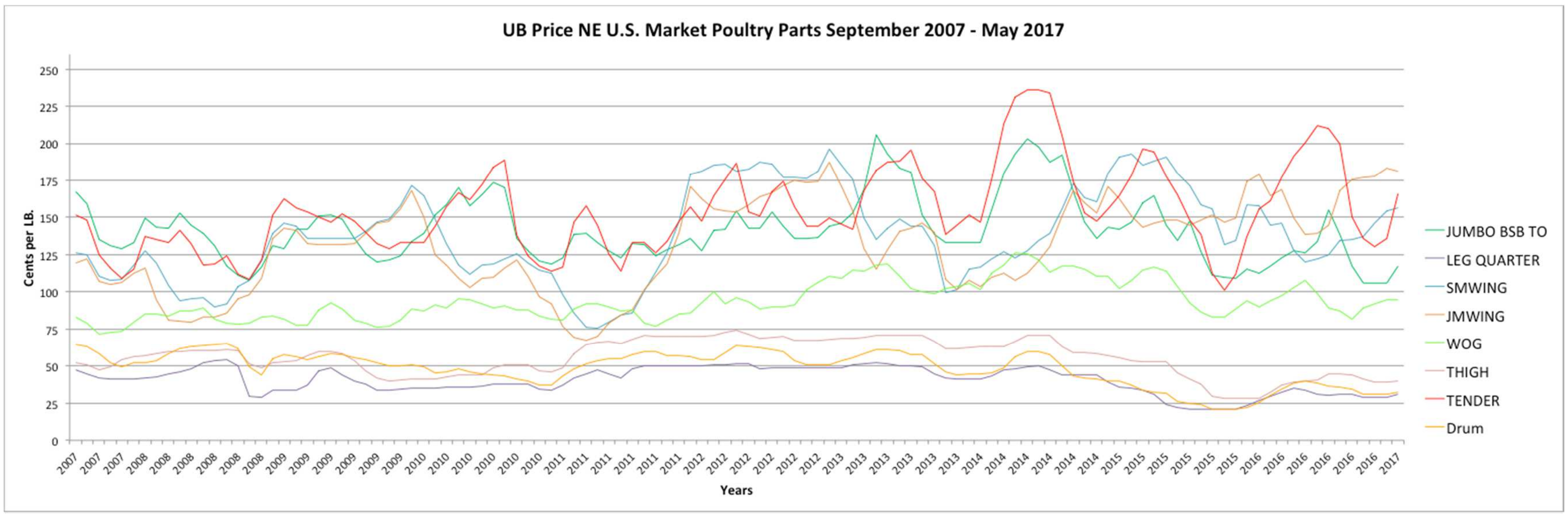

UB Price NE U.S. Market Poultry Parts January 1989 - August 2007
Cents per lb.
Years
275
250
225
200
175
150
125
100
75
50
25
0
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
JUMBO BSB TO
LEG QUARTER
SMWING
JMWING
WOG
THIGH
TENDER
Drum

Figure 2


UB Price NE U.S. Market Poultry Parts September 2007 - May 2017
Cents per LB.
Years
JUMBO BSB TO
LEG QUARTER
SMWING
JMWING
WOG
THIGH
TENDER
Drum

The standard VAR model for four variables was specified as:

$$(1) \quad Y_t = c + T + \sum_{k=1}^{K} \begin{bmatrix} b_{11}(k) & . & . & b_{1n}(k) \\ . & & & \\ . & & & \\ . & & & \\ b_{n1}(k) & . & . & b_{nn}(k) \end{bmatrix} Y_{t-k} + \sum_{l=1}^{11} a_l D_l + \overline{\varepsilon_t}$$

This equation was utilized as the base for all models where the number of variables was increased.

Table 3

Models Analyzed and The Wholesale Broiler Parts Included for Each[14]

Parts	Model 1	Model 2	Model 3	Model 4
SMWING	X	X	X	X
JMWING		X	X	X
WOG	X	X	X	
BSBTO	X	X	X	X
LQ	X	X		
TENDER		X	X	X
DRUM		X		
THIGH		X		
Total Number of Variables Included for Each Model	4	8	5	4

[14] Each "X" represents that part being included in the respective model.

Table 3 displays which variables are included for each model is analyzed. Each equation was adjusted accordingly to accommodate the appropriate number of variables. Lags, trend and constant all remained the same. $\boldsymbol{Y_t}$ represents a 4 x 1 vector containing WOG, BSBTO, WING and LQ prices in period *t* (*t* = 1, …, T), **c** is a vector 4 x 1 of constant terms, **T** is a vector 4 x 1 of trend terms, *k* signifies the lag order of the system, b_{ij} (*k*) are the parameters to be estimated in the *n* by *n* system of equations, where *i* refers to each of *n* estimating equations in the system and *j* refers to each coefficient associated with each *i; D_l* are 11 seasonal dummy variables, a_l are the parameters of the season dummy variable to be estimated and finally ε_t is a 4 x 1 vector of serially uncorrelated random errors, also known as innovations, all with constant variances.

The VAR and univariate models are used to forecast prices 1 to 9 months for out-of-sample forecasts for each variable. The below general univariate model was specified as

$$(2) \quad Y_{it} = c_i + T_i + \sum_{k=1}^{K} [b_i(k)]\, Y_{it-k} + \sum_{l=1}^{11} a_l D_l + \varepsilon_{it}$$

where Y_{it} represents each of the *i* = 1 through 8 variables (SMWING, JMWING, WOG, BSBTO, LQ, TENDER, DRUM and THIGH) and *K* is the lag order of 3[15]. Thus, each univariate AR (*K*) model is nested within the multivariate VAR (*K*) model which contains only *K* lags of the dependent (target forecast) variable along with a trend term, constant and 11 seasonal dummy variables. The univariate AR (*K*) models are a simple individual versions of the multivariate VAR (*K*) model, and both types of models are estimated using OLS. The above equations were utilized for all models and adjusted with the appropriate variables needed.

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[15] McKenzie et al., stated "Preliminary model estimations were performed on VAR systems incorporate from 1 to 12 lags for each variable. The SBIC and likelihood ratio test statistics indicated that a parsimonious VAR system with a lag order of three months was optimal. (McKenzie, Goodwin Jr. , & Carreira, 2007)"

Forecasting of the VAR and AR models were done using a dynamic modeling approach. This is a “multi-step forecasts, where forecasts computed at earlier horizons are used for the lagged dependent variable terms at later horizons For example, the forecasted value computed for time *T* will be used as the first-period lag value for computing the forecast at time *T* + 1, etc. (Estima, 2017)” “Steps” are used to signify in the next period forecasted, in this case months. With the dynamic forecasting approach after each reported forecast the number of observations from which to model from decreases by 1. For example if there are 300 observations the first forecast would utilize all 300. Forecasted step 2 would utilize 299 observations and so on thus you have a decreasing sample size with the more forecasts ahead.

Forecasting performance of all models was then evaluated using the Diebold Mariano tests (DM) based on both the Mean Square Error (MSE) and Mean Absolute Error (MAE) loss functions. The null hypothesis of the DM test is that forecasts from a VAR model are no different than those from an AR specification; H_0: VAR forecasts ≈ AR forecasts. Two alternate hypotheses are considered: (1) VAR forecasts are preferred to AR forecasts (H_{A1}: VAR forecasts ≻ AR forecasts), and (2) vice versa is, (H_{A2}: VAR forecasts ≺ AR forecasts). Forecast performance is also documented with respect to Mean Error (ME), MAE, Root Mean Square Error (RMSE) and Theil’s U Statistic (Theil’s U) which can be expressed as:

$$(3) \quad U = \sqrt{\frac{\sum_{t=1}^{n-1}\left(\frac{F_{t+1} - Y_{t+1}}{Y_t}\right)^2}{\sum_{t=1}^{n-1}\left(\frac{F_{t+1} - Y_{t+1}}{Y_t}\right)^2}}$$

Where U is the Theil’s U-statistic, *F* is the forecasted value of *Y* and *Y* is the actual observation. Theil’s U is “a ratio of the RMS error to the RMS error of the “naïve” forecast of no change in the dependent variable” (Estima, 2017). A unit free measurement ranging from zero to infinity, with unit value being equivalent to a random walk forecast. Overall forecasting accuracy improves with lower ME, MAE, RMSE and Theil's U values.

Section IV – Results, Summary, Conclusion and Implications

Results

To recap, the dependent variables in the estimated models consisted of the main wholesale chicken parts prices that are published by UB. Wholesale parts are: jumbo boneless skinless breast tender out (BSBTO), leg quarter (LQ), small wing (SMWING), jumbo wing (JMWING), whole bird without giblets (WOG), thigh (THIGH), tender (TENDER), and drumstick (DRUM). The most important wholesale parts for the broiler industry are BSBTO, SMWING, JMWING and TENDER. These are all the white meat portions preferred in the United States.

By 1998, all parts listed were being tracked by UB, some parts were tracked long before. Tests for unit roots were performed within RATS utilizing the Augmented Dickey-Fuller test of null hypothesis of existence of a unit root. Unit roots were detected in some variables and not in others. Sims, Stock, and Watson in 1990 "recommend against differencing to transform models to stationary form when it appears likely that the data is integrated. VAR analysis is used to understand the interrelationship between the variables; not the individual parameters" (Sims, Stock, & Watson, 1990). Unit roots were not corrected for in this research. Each unit root test result is presented in the appendix following each model. Each of the models is a comparison of VAR versus AR modeling.

Baseline - Model 1

Model 1 estimates the original McKenzie et al., model VAR comparison with AR utilizing BSBTO, WOG, WING, and LQ. The purpose was to utilize updated data from August

2007 through May 2017 to see if there were substantial changes in parameter values. The broiler industry has changed in several ways since the McKenzie et al., model was estimated. The in-sample data remained the same from January of 1989 through January of 2000. The forecast period data extended from August 2007 through May of 2017. Results of this estimation are shown in Table 1A in the appendix. Forecast statistics are most notably different for WOG and BSBTO from the model estimated by McKenzie et al. WOG in the model estimated by McKenzie et al., had all 9 steps supporting the VAR model. In the new baseline model, the support for modeling is split with steps 1 through 4 having neither model preferred over the other and steps 5 through 9 supporting AR modeling. BSBTO in McKenzie et al., had mixed support of VAR and AR between the model choices with AR being slightly preferred. The new baseline model has all steps supportive of using AR. LQ also exhibited mixed support between VAR and AR however, with the later data the AR model is preferred. For all the 9 steps AR, has support at the one percent level of significance. Overall, for all variables presented, AR support is preferred over VAR modeling 23 times and 13 times neither model is preferred over the other, with no support for VAR. The WING, however, is unchanged from previous research with neither model approach being preferred over the other. When looking at the MAE and RMSE for LQ, the errors are smaller than those of BSBTO and WING for all 9 steps other. WOG has small errors as well through step 5.

Alternative Models - Models 2, 3 and 4

Models 2, 3 and 4 utilize the same observations for the sample period. The alternative models are estimated to understand the price volatility of the white meat portions of the bird which drive overall pricing. White meat portions are also the parts that exhibit the most market volatility; dark meat parts are relatively unchanged in price.

Model 2

Model 2 is an analysis utilizing all parts currently reported by UB data. Results are shown in Table 2A. It is intriguing that the forecast test results fully support AR modeling for all parts except for two steps when forecasting JMWING, steps 8 and 9, when neither model is preferred. Results overwhelmingly support AR and exhibit a statistical significance of one percent. BSBTO, SMWING, THIGH and DRUM each have all 9 steps supporting AR modeling with a one percent statistical significance. LQ, WOG and TENDER have one or two steps that are statistically significant at five percent with all others at the one percent level. JMWING is the only variable that has mixed results at the one, five and ten percent statistical significance interval and two steps that are inconclusive between either model choice. In the original model estimated by McKenzie et al., BSBTO had mixed support for VAR and AR modeling where now it has full support for AR modeling. In the original model by McKenzie et al., LQ had some support for AR modeling at ten percent statistical significance, but now fully supports AR modeling with many steps statistically significant at the one percent level. In the original model by McKenzie et al., WOG had full support for VAR modeling; however, that has now shifted to full support AR modeling at the one percent significance level. It is important to note that model 2 includes 4 additional parts not considered in the original model by McKenzie et al., which could have influenced the changed results. Out of 72 steps, only 2 support neither model choice over the other; 70 steps support AR modeling. The MAE and MSE for LQ, WOG, THIGH and DRUM each have small errors through step 4. Other parts have relative high errors past step 2.

Models 3 and 4

Models 3 and 4 take the approach of looking at the front half or the white meat portions of the bird. The difference between the two is the inclusion of WOG; model 3 has WOG included and model 4 does not. Results from model 3 are presented in table 3A results for model 4 are presented in table 4A. When looking at the most notably intriguing results indicate the inclusion of WOG lend more support for AR modeling than for VAR modeling. However, when the WOG is not included, a number of the variables exhibit mixed support and in some cases, support the null hypothesis that neither model is preferred over the other. BSBTO has the same results in both models 3 and 4. SMWING in model 3 has more steps that have a higher statistical significance than in model 4; both support AR modeling for SMWING. JMWING is interesting in that model, 3 all statistically significant support is for the null hypothesis that neither model is preferred over the other. However, in model 4 there are two instances (steps 8 and 9) where VAR modeling is preferred at the five and one percent statistical significance, respectively. These are the only two steps that show any support for VAR modeling. The WOG, included in model 3 only, has significant support for AR modeling. TENDER in model 3 lends support for AR modeling with a high statistical significance. Nonetheless, in model 4, steps 1 and 2 and steps 7 through 9 support the null hypothesis while steps 3 through 6 support AR modeling with a five and 10 percent statistical significance, respectively. For model 3 the MAE and MSE are relatively small for WOG through step 3, then become larger; all other parts have large ME and MSE after step 1. For model 4 past step 1 for all parts the errors are large.

Summary, Conclusions and Implications

Broiler prices exhibit considerable volatility due to the exogenous factors that determine the prices of parts. Pricing in the broiler industry is reported by third party vendors who gather numerous observations on variables ranging from: cold storage volumes, current and forward contract price negotiations, overall supply and demand and many other measures from the industry. From this information, third parties such as Urner Barry can develop a live pricing sheet for processors to utilize as a base when negotiating new contracts with customers. Economists find the pricing of broiler parts to be more complex due to the vertical integration and all the exogenous factors that play a role in pricing. Therefore, it is important to understand the industry and analyze the most appropriate modeling technique to utilize between VAR and AR to determine the superior modeling approach. Outside factors such as recessionary times, heavy drought periods and extreme outbreaks of AI cause substantial supply and demand shocks to the industry. For example, the drought in 2012 caused a supply shock to chicken wings. In December 2012 chicken prices were up 6 percent, which was more than triple, the increase of overall food prices. The drought resulted in a decrease in the number of chickens produced due to high corn and soybean meal prices. Such factors make modeling complex when attempting to specify models to predict broiler price level over time. This decrease in production resulted in a 1 percent decline in the number of chicken wings consumed for a Super Bowl weekend. National Chicken Council expected approximately 1.23 billion chicken wings would be consumed on that weekend alone (Linn, 2013).

The United States is forecasted to grow with a 2 percent production increase and 4 percent growth in exports (Foreign Agricultural Service, 2017). April 2017 Livestock, Dairy and Poultry Outlook report predicts increasing prices for most chicken parts. Higher prices are expected for 2017, which is most likely showing an increase and strengthening in consumer demand. A constant increase in the total agricultural exports outpacing imports is creating a trade surplus for the U.S. agricultural industry.

The broiler industry continually changes due to changing consumers' tastes and preferences and technological innovation. United States consumers distinctly prefer white meat parts for consumption while dark meat is primarily exported with no value added. Prior to 2007,

groupings of parts are based on essentially consumer preference for BSBTO, TENDER and SMWING, JMWING and then WOG, THIGH, LQ and DRUM. Post 2007, each of these parts began to take on their own identity in the market place. Products today have a significant amount of extra value added that the initial wholesale price only represents a small portion of final product cost. Innovation, consumer's lifestyle changes, varying processors' market share are all reasons the broiler industry is changing at a rapid rate. Technological advancements have allowed the industry to increase in production efficiency, food safety, and product quality.
All the change in the industry makes it imperative to understand the market make-up, pricing and variable interaction between broiler parts. This research was performed to give more insight into understanding pricing in the broiler industry. To do this, econometric modeling approaches were examined using VAR and AR techniques. Monthly average part price data were gathered from January 1998 through May of 2017.

Forecasting results from the models support simpler AR modeling techniques over VAR models. This is especially apparent when trying to utilize all the current wholesale parts that are sold as represented in model 2. Compared to the original model estimated by McKenzie et al., more results favor AR than VAR modeling. The WING is the only part that showed no change from the original model to the base line model. Estimated models for the other parts strongly support the hypothesis that the structure of the industry has changed dramatically since research by McKenzie et al., McKenzie et al., determined from Directed Acyclical Graphs using Sims-Bernanke FEVD results that from the original model each BSBTO, WING and LQ shocks directly affect WOG pricing; meaning WOG was best suited for VAR modeling approach. However, each of the models presented, especially the comparison of models 3 and 4, which are both models using data from 1989 through 2017, show support for AR modeling techniques, not only for WOG but all other parts as well. The MSE and MAE for each of the models across all parts remain relatively small through step 3, after that they tend to become quite large. Forecasting through step 3 (3 months out) is the most suitable; past that, the accuracy weakens dramatically.

Forecasting broiler parts prices employing more accurate forecasting models can help to more efficiently purchase inputs and select products based on pricing. This can have a substantial positive impact on the broiler industry with competitive advantage, cost savings and more market captures, allowing poultry companies increase revenue and give directionality for further growth within their company. This research was purely technical and a theoretical. Outside exogenous factors listed in the literature review help give a foundational understanding on price shocks that are observed in figures 1 and 2. Broiler production requires a multitude of inputs particularly for producing feed production. Feed accounts for approximately 65 percent of the cost to produce a bird (Goodwin, Jr. & Cappas, 2015). Drought, recession and disease outbreak cause exogenous shocks to pricing as well as supply and demand shifters. Other major costs include: heating (propane or natural gas), electricity and water. Research presented ignores the impact of many supply and demand shifters. Models incorporating mitted supply and demand shifters should provide even more accurate forecasts.

This research gives direction for the industry to focus each part rather than the parts as a whole for pricing. That is, under conditions now present in the broiler meat market, it appears more accurate forecast results can be obtained by modeling individual parts independently of other parts rather than being inter-related with all broiler parts can have forecast results.

The broiler industry has changed dramatically since the early 2000's. Prior to further processed value-added products, broiler wholesale prices represented a significant portion of the agreed upon contract price. Value-added products have since grown in market share and are now demanded by consumers. However, value-added products now have a large portion of extra costs added to them. For the broiler industry, this means that the initial wholesale costs of the whole bird before parts are individually priced no longer represent a large portion of the costs. Each individual wholesale part is now broken down significantly further to create even more products.

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Appendix

Table 1A – Baseline Model 1 – Diebold Mariano Test Parameter Estimates VAR (3[16]) vs. AR (3) Out-of-Sample Forecasts January 2000 – May 2017

VAR (3) Estimation Jan. 00 - May 17						AR (3) Estimation Jan. 00 - May 17				D-M p-Value of Test of $H0$: VAR (3) = AR(3)				
										VAR > AR		VAR < AR		Concl.: Data
Step	N	ME	MAE	RMSE	Theil U	ME	MAE	RMSE	Theil U	MSE	MAE	MSE	MAE	Supports
Forecast Statistics for Series WING														
1	209	1.16	6.41	8.04	0.84	0.72	6.33	8.05	0.84	0.47	0.79	0.53	0.21	FTR H_0
2	208	2.75	11.36	13.99	0.88	1.62	11.20	13.96	0.87	0.57	0.77	0.43	0.23	FTR H_0
3	207	4.35	14.76	17.98	0.88	2.52	14.43	17.86	0.88	0.63	0.87	0.37	0.13	FTR H_0
4	206	5.62	17.20	20.90	0.87	3.27	16.76	20.80	0.87	0.61	0.89	0.39	0.11	FTR H_0
5	205	6.69	19.06	23.31	0.86	3.95	18.78	23.22	0.86	0.60	0.77	0.40	0.23	FTR H_0
6	204	7.67	20.37	25.25	0.85	4.64	20.44	25.11	0.84	0.63	0.46	0.37	0.54	FTR H_0
7	203	8.52	21.85	26.91	0.83	5.29	22.20	26.73	0.83	0.65	0.23	0.35	0.77	FTR H_0
8	202	9.21	23.27	28.52	0.82	5.88	23.62	28.22	0.81	0.72	0.24	0.28	0.76	FTR H_0
9	201	9.79	24.40	30.02	0.81	6.41	24.54	29.58	0.80	0.79	0.41	0.21	0.59	FTR H_0
Forecast Statistics for Series WOG														
1	209	0.73	2.89	3.77	0.89	0.56	2.94	3.80	0.89	0.42	0.31	0.58	0.69	FTR H_0
2	208	1.61	4.91	6.20	0.90	1.27	4.98	6.29	0.91	0.36	0.36	0.64	0.64	FTR H_0
3	207	2.40	6.16	7.74	0.88	1.91	6.14	7.78	0.88	0.46	0.55	0.54	0.45	FTR H_0
4	206	3.06	6.94	8.82	0.87	2.43	6.73	8.76	0.87	0.58	0.81	0.42	0.19	FTR H_0
5	205	3.67	7.41	9.60	0.88	2.90	7.06	9.35	0.86	0.76	0.92	0.24	0.08	VAR < AR*
6	204	4.27	7.67	10.13	0.89	3.38	7.18	9.69	0.85	0.88	0.97	0.12	0.03	VAR < AR**
7	203	4.79	7.94	10.55	0.89	3.81	7.47	10.13	0.86	0.87	0.97	0.13	0.03	VAR < AR**
8	202	5.26	8.20	10.85	0.91	4.20	7.87	10.49	0.88	0.83	0.90	0.17	0.10	VAR < AR*
9	201	5.69	8.35	11.05	0.93	4.58	8.08	10.69	0.90	0.82	0.83	0.18	0.17	VAR < AR*

[16] 3 signifies the month lag parameter

Table 1A Cont. – Baseline Model 1 – Diebold Mariano Test Parameter Estimates VAR (3) vs. AR (3) Out-of-Sample Forecasts
January 2000 – May 2017

VAR (3) Estimation Jan. 00 - May 17						AR (3) Estimation Jan. 00 - May 17				D-M p-Value of Test of $H0$: VAR (3) = AR(3)				
										VAR > AR		VAR < AR		Concl.: Data
Step	N	ME	MAE	RMSE	Theil U	ME	MAE	RMSE	Theil U	MSE	MAE	MSE	MAE	Supports
Forecast Statistics for Series BSBTO														
1	209	1.37	8.19	10.55	0.87	1.10	7.92	10.18	0.84	0.99	0.96	0.01	0.04	VAR < AR**
2	208	2.95	12.01	16.23	0.82	2.20	11.59	15.60	0.78	1.00	0.96	0.00	0.04	VAR < AR**
3	207	4.63	15.06	20.43	0.80	3.33	14.12	19.46	0.77	1.00	1.00	0.00	0.00	VAR < AR***
4	206	6.07	17.48	23.42	0.79	4.34	16.28	22.16	0.75	1.00	1.00	0.00	0.00	VAR < AR***
5	205	7.30	18.54	25.13	0.78	5.25	17.58	23.82	0.74	1.00	0.99	0.00	0.01	VAR < AR***
6	204	8.41	19.03	25.91	0.77	6.12	18.23	24.69	0.73	1.00	0.98	0.00	0.02	VAR < AR**
7	203	9.35	19.48	26.16	0.78	6.91	18.60	25.09	0.75	1.00	0.99	0.00	0.01	VAR < AR**
8	202	10.21	19.63	26.22	0.81	7.70	18.92	25.34	0.78	0.99	0.96	0.01	0.04	VAR < AR**
9	201	10.84	20.06	26.56	0.85	8.31	19.37	25.86	0.83	0.97	0.96	0.03	0.04	VAR < AR**
Forecast Statistics for Series LQ														
1	209	0.30	1.98	2.85	0.94	0.20	1.82	2.71	0.90	0.99	1.00	0.01	0.00	VAR < AR***
2	208	0.68	3.75	5.01	0.99	0.46	3.47	4.72	0.93	0.99	1.00	0.01	0.00	VAR < AR***
3	207	1.02	4.98	6.39	0.99	0.72	4.64	5.99	0.93	0.99	0.99	0.01	0.01	VAR < AR***
4	206	1.28	5.92	7.43	0.98	0.91	5.48	6.95	0.92	1.00	1.00	0.00	0.00	VAR < AR***
5	205	1.52	6.50	8.21	0.98	1.09	6.02	7.65	0.91	1.00	1.00	0.00	0.00	VAR < AR***
6	204	1.77	6.92	8.80	0.98	1.27	6.43	8.19	0.91	1.00	1.00	0.00	0.00	VAR < AR***
7	203	2.00	7.18	9.18	0.99	1.43	6.71	8.58	0.92	1.00	0.99	0.00	0.01	VAR < AR***
8	202	2.23	7.35	9.45	1.00	1.58	6.83	8.82	0.94	1.00	1.00	0.00	0.00	VAR < AR***
9	201	2.43	7.52	9.69	1.02	1.73	6.96	8.98	0.95	1.00	1.00	0.00	0.00	VAR < AR***

Note:* Indicatesstatistical significance at α = 10%; ** Indicates statistical significance at α = 5%;
*** Indicates statistical significance at α = 1%

Table 1B – Unit Root Results Presented By RATS – Baseline Model 1

Results of Augmented Dickey-Fuller Test of Null Hypothesis of
Existence of a Unit-Root Given by RATS
Model 1 - Estimation January 2000 - May 2017

Variable	Model Specification Selected	Test Statistic	Critical Value (α = 1%)	Critical Value (α = 5%)	Critical Value (α = 10%)	AIC Lag	Test Conclusion
WOG	With Intercept	-0.775	-3.452	-2.871	-2.572	13	Unit Root
WING	With Intercept	0.185	-3.453	-2.871	-2.572	24	Unit Root
BSBTO	With Intercept	-2.503	-3.453	-2.871	-2.572	24	Unit Root
LQ	With Intercept	-2.160	-3.452	-2.870	-2.571	7	Unit Root

Table 2A – Model 2 – Diebold Mariano Test Parameter Estimates VAR (3) vs. AR (3) Out-of-Sample Forecasts
August 2007 – May 2017

		VAR (3) Estimation August 07 - May 17				AR (3) Estimation August 07 - May 17				D-M p-Value of Test of $H0$: VAR (3) = AR(3)				
										VAR > AR		VAR < AR		Concl.: Data
Step	N	ME	MAE	RMSE	Theil U	ME	MAE	RMSE	Theil U	MSE	MAE	MSE	MAE	Supports
Forecast Statistics for Series BSBTO														
1	118	0.343	8.920	10.897	0.958	-0.312	6.959	8.725	0.767	1.000	1.000	0.000	0.000	VAR < AR***
2	117	-0.184	14.650	17.896	0.982	-0.696	10.215	12.729	0.699	1.000	1.000	0.000	0.000	VAR < AR***
3	116	-0.647	17.903	22.579	0.966	-1.001	11.863	14.945	0.639	1.000	1.000	0.000	0.000	VAR < AR***
4	115	-0.900	20.703	26.360	0.960	-1.262	13.603	16.751	0.610	1.000	1.000	0.000	0.000	VAR < AR***
5	114	-1.187	23.031	28.953	0.955	-1.570	14.488	17.876	0.590	1.000	1.000	0.000	0.000	VAR < AR***
6	113	-1.403	24.705	30.088	0.952	-1.764	15.185	18.654	0.590	1.000	1.000	0.000	0.000	VAR < AR***
7	112	-1.585	25.606	30.223	0.963	-1.899	15.792	19.308	0.615	1.000	1.000	0.000	0.000	VAR < AR***
8	111	-1.699	26.064	30.260	1.000	-2.047	16.289	20.079	0.663	1.000	1.000	0.000	0.000	VAR < AR***
9	110	-1.584	25.560	30.051	1.050	-2.083	16.645	20.577	0.719	1.000	1.000	0.000	0.000	VAR < AR***
Forecast Statistics for Series LQ														
1	118	-0.682	2.504	3.400	1.138	-0.554	1.955	2.890	0.967	1.000	1.000	0.000	0.000	VAR < AR***
2	117	-1.773	4.673	6.082	1.230	-1.337	3.639	5.017	1.015	1.000	1.000	0.000	0.000	VAR < AR***
3	116	-2.709	5.933	7.691	1.234	-2.041	4.664	6.307	1.012	1.000	1.000	0.000	0.000	VAR < AR***
4	115	-3.555	6.713	8.771	1.219	-2.700	5.400	7.336	1.019	1.000	1.000	0.000	0.000	VAR < AR***
5	114	-4.280	7.291	9.603	1.209	-3.313	6.074	8.183	1.030	1.000	0.999	0.000	0.001	VAR < AR***
6	113	-4.843	7.829	10.258	1.206	-3.873	6.697	8.927	1.050	0.999	0.998	0.001	0.002	VAR < AR***
7	112	-5.257	8.113	10.614	1.210	-4.387	7.218	9.540	1.088	0.998	0.990	0.002	0.010	VAR < AR***
8	111	-5.490	8.221	10.843	1.222	-4.856	7.581	10.056	1.133	0.986	0.953	0.014	0.047	VAR < AR**
9	110	-5.722	8.578	11.062	1.233	-5.318	7.829	10.489	1.169	0.960	0.975	0.040	0.025	VAR < AR**

Table 2A Cont. – Model 2 – Diebold Mariano Test Parameter Estimates VAR (3) vs. AR (3) Out-of-Sample Forecasts
August 2007 – May 2017

		VAR (3) Estimation August 07 - May 17				AR (3) Estimation August 07 - May 17				D-M p-Value of Test of $H0$: VAR (3) = AR(3)				
										VAR > AR		VAR < AR		Concl.: Data
Step	N	ME	MAE	RMSE	Theil U	ME	MAE	RMSE	Theil U	MSE	MAE	MSE	MAE	Supports
Forecast Statistics for Series SMWING														
1	118	-0.379	7.109	8.950	0.877	-0.213	6.141	7.865	0.771	0.999	0.999	0.001	0.001	VAR < AR***
2	117	-0.716	12.710	15.966	0.920	-0.502	11.116	13.895	0.800	0.998	0.994	0.002	0.006	VAR < AR***
3	116	-1.208	16.998	21.343	0.944	-0.844	14.575	18.338	0.811	1.000	0.998	0.000	0.002	VAR < AR***
4	115	-1.953	21.332	26.317	0.973	-1.254	17.343	22.236	0.822	1.000	1.000	0.000	0.000	VAR < AR***
5	114	-2.877	25.151	30.377	0.991	-1.686	20.456	25.505	0.832	1.000	1.000	0.000	0.000	VAR < AR***
6	113	-3.563	27.605	33.249	0.988	-1.916	22.984	27.887	0.829	1.000	1.000	0.000	0.000	VAR < AR***
7	112	-4.068	29.606	35.138	0.958	-2.061	25.343	29.731	0.811	1.000	1.000	0.000	0.000	VAR < AR***
8	111	-4.548	31.242	36.530	0.920	-2.311	27.390	31.542	0.795	1.000	0.998	0.000	0.002	VAR < AR***
9	110	-4.632	32.655	37.807	0.891	-2.474	28.891	33.282	0.784	0.999	0.998	0.001	0.002	VAR < AR***
Forecast Statistics for Series JMWING														
1	118	1.160	6.734	8.757	0.831	0.517	6.011	7.806	0.740	0.990	0.977	0.010	0.023	VAR < AR**
2	117	2.389	12.049	15.814	0.899	1.175	10.612	13.926	0.791	0.974	0.977	0.026	0.023	VAR < AR**
3	116	3.036	16.217	20.952	0.933	1.740	14.397	18.318	0.816	0.988	0.976	0.012	0.024	VAR < AR**
4	115	3.200	20.020	25.080	0.946	2.322	17.493	21.958	0.828	0.997	0.993	0.003	0.007	VAR < AR***
5	114	3.058	22.219	27.661	0.937	2.746	19.623	24.217	0.820	0.998	0.989	0.002	0.011	VAR < AR**
6	113	3.148	23.797	29.277	0.924	3.224	21.120	25.814	0.814	0.996	0.991	0.004	0.009	VAR < AR***
7	112	3.456	24.232	30.133	0.894	3.760	22.600	27.184	0.806	0.984	0.911	0.016	0.089	VAR < AR*
8	111	3.744	24.590	30.655	0.859	4.164	24.148	28.657	0.803	0.923	0.636	0.077	0.364	FTR H_0
9	110	4.379	25.707	31.375	0.832	4.639	25.501	30.054	0.797	0.834	0.564	0.166	0.436	FTR H_0

Table 2A Cont. – Model 2 – Diebold Mariano Test Parameter Estimates VAR (3) vs. AR (3) Out-of-Sample Forecasts
August 2007 – May 2017

		VAR (3) Estimation August 07 - May 17				AR (3) Estimation August 07 - May 17				D-M p-Value of Test of $H0$: VAR (3) = AR(3)				
										VAR > AR		VAR < AR		Concl.: Data
Step	N	ME	MAE	RMSE	Theil U	ME	MAE	RMSE	Theil U	MSE	MAE	MSE	MAE	Supports
Forecast Statistics for Series WOG														
1	118	-0.042	3.477	4.442	0.918	-0.100	3.166	3.934	0.813	0.983	0.968	0.017	0.032	VAR < AR**
2	117	-0.525	5.902	7.507	0.970	-0.240	5.021	6.298	0.814	0.998	0.996	0.002	0.004	VAR < AR***
3	116	-0.985	7.295	9.437	0.951	-0.346	6.204	7.712	0.777	1.000	0.996	0.000	0.004	VAR < AR***
4	115	-1.335	8.181	10.574	0.946	-0.437	6.711	8.532	0.763	1.000	0.999	0.000	0.001	VAR < AR***
5	114	-1.653	9.020	11.531	0.968	-0.528	6.700	8.945	0.751	1.000	1.000	0.000	0.000	VAR < AR***
6	113	-1.895	9.904	12.477	1.019	-0.610	7.019	9.286	0.758	1.000	1.000	0.000	0.000	VAR < AR***
7	112	-2.079	10.285	13.071	1.030	-0.708	7.406	9.766	0.770	1.000	1.000	0.000	0.000	VAR < AR***
8	111	-2.202	10.583	13.374	1.052	-0.873	7.922	10.231	0.805	1.000	1.000	0.000	0.000	VAR < AR***
9	110	-2.188	10.685	13.362	1.074	-0.988	8.266	10.579	0.850	1.000	1.000	0.000	0.000	VAR < AR***
Forecast Statistics for Series THIGH														
1	118	0.020	2.523	3.392	1.139	-0.260	1.907	2.690	0.903	0.978	0.999	0.022	0.001	VAR < AR***
2	117	-0.376	4.896	6.309	1.212	-0.611	3.764	4.947	0.950	0.983	0.999	0.017	0.001	VAR < AR***
3	116	-1.022	6.701	8.255	1.204	-0.947	5.260	6.614	0.965	0.999	1.000	0.001	0.000	VAR < AR***
4	115	-1.828	8.017	9.910	1.235	-1.380	6.328	7.932	0.989	1.000	1.000	0.000	0.000	VAR < AR***
5	114	-2.598	9.021	11.389	1.271	-1.830	7.070	9.096	1.015	1.000	1.000	0.000	0.000	VAR < AR***
6	113	-3.263	9.947	12.606	1.292	-2.309	7.714	10.195	1.045	1.000	1.000	0.000	0.000	VAR < AR***
7	112	-3.827	10.595	13.574	1.299	-2.769	8.219	11.198	1.071	1.000	1.000	0.000	0.000	VAR < AR***
8	111	-4.239	11.245	14.376	1.294	-3.189	8.867	12.206	1.098	1.000	1.000	0.000	0.000	VAR < AR***
9	110	-4.622	11.821	15.006	1.284	-3.637	9.470	13.098	1.121	1.000	1.000	0.000	0.000	VAR < AR***

Table 2A Cont. – Model 2 – Diebold Mariano Test Parameter Estimates VAR (3) vs. AR (3) Out-of-Sample Forecasts
August 2007 – May 2017

		VAR (3) Estimation August 07 - May 17				AR (3) Estimation August 07 - May 17				D-M p-Value of Test of $H0$: VAR (3) = AR(3)				
										VAR > AR		VAR < AR		Concl.: Data
Step	N	ME	MAE	RMSE	Theil U	ME	MAE	RMSE	Theil U	MSE	MAE	MSE	MAE	Supports
Forecast Statistics for Series TENDER														
1	118	0.449	10.274	13.431	0.892	1.431	9.156	11.383	0.756	0.986	0.974	0.014	0.026	VAR < AR**
2	117	0.219	18.102	23.950	0.942	3.401	15.312	18.093	0.711	0.989	0.988	0.011	0.012	VAR < AR**
3	116	-0.042	23.776	30.593	0.935	5.477	17.373	22.292	0.681	0.999	1.000	0.001	0.000	VAR < AR***
4	115	0.418	26.397	33.755	0.892	7.373	18.608	24.405	0.645	1.000	1.000	0.000	0.000	VAR < AR***
5	114	1.559	28.590	36.355	0.878	8.707	19.416	25.608	0.618	1.000	1.000	0.000	0.000	VAR < AR***
6	113	3.252	30.208	37.825	0.884	9.841	19.796	26.198	0.612	1.000	1.000	0.000	0.000	VAR < AR***
7	112	5.016	29.779	37.618	0.900	10.819	20.280	26.418	0.632	1.000	1.000	0.000	0.000	VAR < AR***
8	111	6.594	29.038	36.413	0.921	11.537	20.857	26.600	0.673	1.000	1.000	0.000	0.000	VAR < AR***
9	110	8.328	28.812	35.062	0.943	12.344	21.267	26.829	0.722	1.000	1.000	0.000	0.000	VAR < AR***
Forecast Statistics for Series DRUM														
1	118	-0.607	2.399	3.111	0.971	-0.501	2.079	2.776	0.867	0.988	0.996	0.012	0.004	VAR < AR***
2	117	-1.790	5.009	6.317	1.135	-1.247	4.080	5.192	0.933	0.999	1.000	0.001	0.000	VAR < AR***
3	116	-2.957	6.674	8.379	1.160	-2.003	5.366	6.707	0.928	1.000	1.000	0.000	0.000	VAR < AR***
4	115	-4.076	7.970	9.851	1.160	-2.804	6.201	7.908	0.931	1.000	1.000	0.000	0.000	VAR < AR***
5	114	-5.019	8.977	11.110	1.172	-3.547	6.909	9.023	0.952	1.000	1.000	0.000	0.000	VAR < AR***
6	113	-5.718	9.883	12.167	1.200	-4.215	7.498	10.119	0.998	1.000	1.000	0.000	0.000	VAR < AR***
7	112	-6.275	10.572	13.024	1.244	-4.889	8.279	11.127	1.063	1.000	1.000	0.000	0.000	VAR < AR***
8	111	-6.678	11.171	13.660	1.296	-5.516	8.864	12.046	1.143	0.998	1.000	0.002	0.000	VAR < AR***
9	110	-7.139	11.735	14.151	1.346	-6.175	9.425	12.765	1.214	0.994	1.000	0.006	0.000	VAR < AR***

Note:* Indicatesstatistical significance at α = 10%; ** Indicates statistical significance at α = 5%;
*** Indicates statistical significance at α = 1%

Table 2B – Unit Root Results Presented By RATS – Model 2

Results of Augmented Dickey-Fuller Test of Null Hypothesis of
Existence of a Unit-Root Given by RATS
Model 2 - Estimation August 2007 - May 17

Variable	Model Specification Selected	Test Statistic	Critical Value (α = 1%)	Critical Value (α = 5%)	Critical Value (α = 10%)	AIC Lag	Test Conclusion
JBSBTO	With Intercept	-4.237	-3.465	-2.877	-2.575	16	Significant at α = 1%
JMWING	With Intercept	0.089	-3.467	-2.877	-2.575	24	Unit Root
SMWING	With Intercept	-0.779	-3.467	-2.877	-2.575	24	Unit Root
TENDER	With Intercept	-2.621	-3.467	-2.877	-2.575	24	Significant at α = 10%
WOG	With Intercept	-1.824	-3.455	-2.872	-2.572	24	Unit Root
LQ	With Intercept	-2.914	-3.452	-2.870	-2.571	6	Significant at α = 5%
THIGH	With Intercept	-2.322	-3.463	-2.876	-2.574	3	Unit Root
DRUM	With Intercept	-1.800	-3.467	-2.877	-2.575	23	Unit Root

Table 3A – Model 3 – Diebold Mariano Test Parameter Estimates VAR (3) vs. AR (3) Out-of-Sample Forecasts
August 2007 – May 2017

		VAR (3) Estimation August 07 - May 2017				AR (3) August 07 - May 17				D-M p-Value of Test of $H0$: VAR (3) = AR(3)				
										VAR > AR		VAR < AR		Concl.: Data
Step	N	ME	MAE	RMSE	Theil U	ME	MAE	RMSE	Theil U	MSE	MAE	MSE	MAE	Supports
Forecast Statistics for Series BSBTO														
1	118	-0.285	8.171	9.872	0.868	-0.312	6.959	8.725	0.767	1.000	1.000	0.000	0.000	VAR < AR***
2	117	-1.016	12.754	15.650	0.859	-0.696	10.215	12.729	0.699	1.000	1.000	0.000	0.000	VAR < AR***
3	116	-1.288	15.169	19.592	0.838	-1.001	11.863	14.945	0.639	1.000	1.000	0.000	0.000	VAR < AR***
4	115	-1.253	17.496	22.564	0.822	-1.262	13.603	16.751	0.610	1.000	1.000	0.000	0.000	VAR < AR***
5	114	-1.189	18.743	24.378	0.804	-1.570	14.488	17.876	0.590	1.000	1.000	0.000	0.000	VAR < AR***
6	113	-0.960	20.339	25.015	0.792	-1.764	15.185	18.654	0.590	1.000	1.000	0.000	0.000	VAR < AR***
7	112	-0.622	20.833	24.625	0.785	-1.899	15.792	19.308	0.615	1.000	1.000	0.000	0.000	VAR < AR***
8	111	-0.306	20.578	24.176	0.799	-2.047	16.289	20.079	0.663	1.000	1.000	0.000	0.000	VAR < AR***
9	110	0.077	20.000	23.513	0.822	-2.083	16.645	20.577	0.719	0.999	1.000	0.001	0.000	VAR < AR***
Forecast Statistics for Series SMWING														
1	118	-0.491	6.490	8.363	0.819	-0.213	6.141	7.865	0.771	0.976	0.918	0.024	0.082	VAR < AR**
2	117	-0.942	11.708	14.753	0.850	-0.502	11.116	13.895	0.800	0.975	0.895	0.025	0.105	VAR < AR*
3	116	-1.350	15.724	19.794	0.875	-0.844	14.575	18.338	0.811	0.995	0.967	0.005	0.033	VAR < AR**
4	115	-1.862	19.970	24.507	0.906	-1.254	17.343	22.236	0.822	1.000	1.000	0.000	0.000	VAR < AR***
5	114	-2.527	23.525	28.351	0.925	-1.686	20.456	25.505	0.832	1.000	1.000	0.000	0.000	VAR < AR***
6	113	-3.027	26.344	31.114	0.925	-1.916	22.984	27.887	0.829	1.000	1.000	0.000	0.000	VAR < AR***
7	112	-3.446	28.463	33.006	0.900	-2.061	25.343	29.731	0.811	1.000	0.999	0.000	0.001	VAR < AR***
8	111	-4.050	30.084	34.251	0.863	-2.311	27.390	31.542	0.795	0.996	0.997	0.004	0.003	VAR < AR***
9	110	-4.341	31.194	35.421	0.835	-2.474	28.891	33.282	0.784	0.982	0.991	0.018	0.009	VAR < AR***

Table 3A Cont. – Model 3 – Diebold Mariano Test Parameter Estimates VAR (3) vs. AR (3) Out-of-Sample Forecasts
August 2007 – May 2017

		VAR (3) Estimation August 07 - May 2017				AR (3) August 07 - May 17				D-M p-Value of Test of $H0$: VAR (3) = AR(3) VAR > AR		VAR < AR		Concl.: Data
Step	N	ME	MAE	RMSE	Theil U	ME	MAE	RMSE	Theil U	MSE	MAE	MSE	MAE	Supports
Forecast Statistics for Series JMWING														
1	118	0.674	6.145	7.992	0.758	0.517	6.011	7.806	0.740	0.765	0.674	0.235	0.326	FTR H_0
2	117	1.516	10.885	13.964	0.794	1.175	10.612	13.926	0.791	0.531	0.691	0.469	0.309	FTR H_0
3	116	2.253	14.426	18.456	0.822	1.740	14.397	18.318	0.816	0.582	0.516	0.418	0.484	FTR H_0
4	115	2.854	18.186	22.597	0.852	2.322	17.493	21.958	0.828	0.796	0.788	0.204	0.212	FTR H_0
5	114	3.108	20.624	25.198	0.854	2.746	19.623	24.217	0.820	0.871	0.859	0.129	0.141	FTR H_0
6	113	3.369	21.933	26.819	0.846	3.224	21.120	25.814	0.814	0.862	0.815	0.138	0.185	FTR H_0
7	112	3.700	22.729	27.815	0.825	3.760	22.600	27.184	0.806	0.751	0.557	0.249	0.443	FTR H_0
8	111	3.860	23.280	28.460	0.798	4.164	24.148	28.657	0.803	0.417	0.168	0.583	0.832	FTR H_0
9	110	4.304	23.933	29.274	0.777	4.639	25.501	30.054	0.797	0.201	0.046	0.799	0.954	FTR H_0
Forecast Statistics for Series WOG														
1	118	-0.410	3.396	4.255	0.880	-0.100	3.166	3.934	0.813	0.981	0.955	0.019	0.045	VAR < AR**
2	117	-1.048	5.739	7.206	0.931	-0.240	5.021	6.298	0.814	0.997	0.996	0.003	0.004	VAR < AR***
3	116	-1.519	7.022	9.144	0.921	-0.346	6.204	7.712	0.777	0.999	0.986	0.001	0.014	VAR < AR**
4	115	-1.831	7.889	10.351	0.926	-0.437	6.711	8.532	0.763	1.000	0.997	0.000	0.003	VAR < AR***
5	114	-2.033	8.656	11.184	0.938	-0.528	6.700	8.945	0.751	1.000	1.000	0.000	0.000	VAR < AR***
6	113	-2.095	9.190	11.897	0.971	-0.610	7.019	9.286	0.758	1.000	1.000	0.000	0.000	VAR < AR***
7	112	-2.079	9.416	12.358	0.974	-0.708	7.406	9.766	0.770	1.000	1.000	0.000	0.000	VAR < AR***
8	111	-2.079	9.773	12.678	0.998	-0.873	7.922	10.231	0.805	1.000	1.000	0.000	0.000	VAR < AR***
9	110	-1.992	10.043	12.765	1.026	-0.988	8.266	10.579	0.850	1.000	1.000	0.000	0.000	VAR < AR***

Table 3A Cont. – Model 3 – Diebold Mariano Test Parameter Estimates VAR (3) vs. AR (3) Out-of-Sample Forecasts
August 2007 – May 2017

VAR (3) Estimation August 07 - May 2017						AR (3) August 07 - May 17				D-M p-Value of Test of $H0$: VAR (3) = AR(3)				
										VAR > AR		VAR < AR		Concl.: Data
Step	N	ME	MAE	RMSE	Theil U	ME	MAE	RMSE	Theil U	MSE	MAE	MSE	MAE	Supports
Forecast Statistics for Series TENDER														
1	118	0.260	9.414	11.962	0.794	1.431	9.156	11.383	0.756	0.917	0.723	0.083	0.277	FTR H_0
2	117	-0.038	16.502	20.315	0.799	3.401	15.312	18.093	0.711	0.985	0.894	0.015	0.106	FTR H_0
3	116	-0.176	21.562	26.610	0.813	5.477	17.373	22.292	0.681	0.999	1.000	0.001	0.000	VAR < AR***
4	115	0.335	23.896	30.597	0.808	7.373	18.608	24.405	0.645	1.000	1.000	0.000	0.000	VAR < AR***
5	114	1.385	25.174	33.072	0.799	8.707	19.416	25.608	0.618	1.000	1.000	0.000	0.000	VAR < AR***
6	113	3.037	26.395	33.933	0.793	9.841	19.796	26.198	0.612	1.000	1.000	0.000	0.000	VAR < AR***
7	112	4.939	26.005	33.410	0.799	10.819	20.280	26.418	0.632	1.000	0.999	0.000	0.001	VAR < AR***
8	111	6.758	25.592	32.393	0.820	11.537	20.857	26.600	0.673	0.998	0.995	0.002	0.005	VAR < AR***
9	110	8.709	25.392	31.595	0.850	12.344	21.267	26.829	0.722	0.996	0.995	0.004	0.005	VAR < AR***

Note:* Indicatesstatistical significance at α = 10%; ** Indicates statistical significance at α = 5%;
*** Indicates statistical significance at α = 1%

Table 3B – Unit Root Results Presented By RATS – Model 3

Results of Augmented Dickey-Fuller Test of Null Hypothesis of Existence of a Unit-Root Given by RATS
Model 3 - Estimation August 2007 - May 2017

Variable	Model Specification Selected	Test Statistic	Critical Value (α = 1%)	Critical Value (α = 5%)	Critical Value (α = 10%)	AIC Lag	Test Conclusion
JBSBTO	With Intercept	-4.237	-3.465	-2.877	-2.575	16	Significant at α = 1%
JMWING	With Intercept	0.089	-3.467	-2.877	-2.575	24	Unit Root
SMWING	With Intercept	-0.779	-3.467	-2.877	-2.575	24	Unit Root
TENDER	With Intercept	-2.621	-3.467	-2.877	-2.575	24	Significant at α = 10%
WOG	With Intercept	-1.824	-3.455	-2.872	-2.572	24	Unit Root

Table 4A – Model 4 – Diebold Mariano Test Parameter Estimates VAR (3) vs. AR (3) Out-of-Sample Forecasts
August 2007 – May 2017

VAR (3) Estimation August 07 - May 2017						AR (3) August 07 - May 17				D-M *p*-Value of Test of *H*0: VAR (3) = AR(3)				
										VAR > AR		VAR < AR		Concl.: Data
Step	N	ME	MAE	RMSE	Theil U	ME	MAE	RMSE	Theil U	MSE	MAE	MSE	MAE	Supports
Forecast Statistics for Series BSBTO														
1	118	-0.766	7.644	9.348	0.822	-0.312	6.959	8.725	0.767	0.999	1.000	0.001	0.000	VAR < AR***
2	117	-1.971	11.591	14.192	0.779	-0.696	10.215	12.729	0.699	1.000	1.000	0.000	0.000	VAR < AR***
3	116	-2.770	13.615	17.049	0.729	-1.001	11.863	14.945	0.639	1.000	1.000	0.000	0.000	VAR < AR***
4	115	-3.213	15.176	19.014	0.693	-1.262	13.603	16.751	0.610	0.999	0.997	0.001	0.003	VAR < AR***
5	114	-3.575	16.019	20.175	0.666	-1.570	14.488	17.876	0.590	0.998	0.996	0.002	0.004	VAR < AR***
6	113	-3.715	16.843	20.872	0.661	-1.764	15.185	18.654	0.590	0.998	0.998	0.002	0.002	VAR < AR***
7	112	-3.717	17.459	21.292	0.678	-1.899	15.792	19.308	0.615	0.997	0.998	0.003	0.002	VAR < AR***
8	111	-3.666	18.036	21.873	0.723	-2.047	16.289	20.079	0.663	0.996	0.999	0.004	0.001	VAR < AR***
9	110	-3.489	18.206	22.075	0.772	-2.083	16.645	20.577	0.719	0.993	0.997	0.008	0.003	VAR < AR***
Forecast Statistics for Series SMWING														
1	118	-0.668	6.448	8.233	0.807	-0.213	6.141	7.865	0.771	0.972	0.948	0.028	0.052	VAR < AR*
2	117	-1.307	11.491	14.373	0.828	-0.502	11.116	13.895	0.800	0.919	0.859	0.081	0.141	VAR < AR*
3	116	-2.061	15.301	19.181	0.848	-0.844	14.575	18.338	0.811	0.978	0.951	0.022	0.049	VAR < AR**
4	115	-3.011	19.002	23.659	0.875	-1.254	17.343	22.236	0.822	0.996	0.999	0.004	0.001	VAR < AR***
5	114	-4.100	22.171	27.352	0.892	-1.686	20.456	25.505	0.832	0.998	0.997	0.002	0.003	VAR < AR***
6	113	-4.936	25.177	30.168	0.897	-1.916	22.984	27.887	0.829	0.999	0.999	0.001	0.001	VAR < AR***
7	112	-5.620	27.612	32.165	0.877	-2.061	25.343	29.731	0.811	0.999	0.999	0.001	0.001	VAR < AR***
8	111	-6.349	29.305	33.614	0.847	-2.311	27.390	31.542	0.795	0.994	0.992	0.006	0.008	VAR < AR***
9	110	-6.737	30.540	34.830	0.821	-2.474	28.891	33.282	0.784	0.965	0.979	0.035	0.021	VAR < AR**

Table 4A Cont. – Model 4 – Diebold Mariano Test Parameter Estimates VAR (3) vs. AR (3) Out-of-Sample Forecasts
August 2007 – May 2017

VAR (3) Estimation August 07 - May 2017						AR (3) August 07 - May 17				D-M p-Value of Test of $H0$: VAR (3) = AR(3)				
										VAR > AR		VAR < AR		Concl.: Data
Step	N	ME	MAE	RMSE	Theil U	ME	MAE	RMSE	Theil U	MSE	MAE	MSE	MAE	Supports
Forecast Statistics for Series JMWING														
1	118	0.614	6.069	8.032	0.762	0.517	6.011	7.806	0.740	0.867	0.603	0.133	0.397	FTR H_0
2	117	1.418	10.900	13.990	0.795	1.175	10.612	13.926	0.791	0.562	0.744	0.438	0.256	FTR H_0
3	116	1.890	14.588	18.223	0.812	1.740	14.397	18.318	0.816	0.433	0.634	0.567	0.366	FTR H_0
4	115	2.073	18.076	21.823	0.823	2.322	17.493	21.958	0.828	0.418	0.807	0.582	0.193	FTR H_0
5	114	1.919	20.112	23.941	0.811	2.746	19.623	24.217	0.820	0.349	0.751	0.651	0.249	FTR H_0
6	113	1.847	21.098	25.342	0.799	3.224	21.120	25.814	0.814	0.254	0.487	0.746	0.513	FTR H_0
7	112	1.896	21.943	26.423	0.784	3.760	22.600	27.184	0.806	0.133	0.166	0.867	0.834	FTR H_0
8	111	1.845	22.917	27.290	0.765	4.164	24.148	28.657	0.803	0.016	0.029	0.984	0.971	VAR > AR**
9	110	2.119	23.452	28.138	0.746	4.639	25.501	30.054	0.797	0.002	0.002	0.998	0.998	VAR > AR***
Forecast Statistics for Series TENDER														
1	118	-0.117	9.071	11.630	0.772	1.431	9.156	11.383	0.756	0.737	0.416	0.263	0.584	FTR H_0
2	117	-0.896	15.826	19.259	0.757	3.401	15.312	18.093	0.711	0.893	0.727	0.107	0.273	FTR H_0
3	116	-1.666	20.226	24.514	0.749	5.477	17.373	22.292	0.681	0.962	0.994	0.038	0.006	VAR < AR**
4	115	-1.790	21.818	27.163	0.718	7.373	18.608	24.405	0.645	0.966	0.992	0.034	0.008	VAR < AR**
5	114	-1.273	21.533	28.416	0.686	8.707	19.416	25.608	0.618	0.952	0.923	0.048	0.077	VAR < AR**
6	113	-0.004	21.654	28.592	0.668	9.841	19.796	26.198	0.612	0.911	0.874	0.089	0.126	FTR H_0
7	112	1.614	21.760	28.025	0.670	10.819	20.280	26.418	0.632	0.810	0.816	0.190	0.184	FTR H_0
8	111	3.250	22.333	27.750	0.702	11.537	20.857	26.600	0.673	0.738	0.822	0.262	0.178	FTR H_0
9	110	5.066	22.559	27.873	0.750	12.344	21.267	26.829	0.722	0.750	0.816	0.250	0.184	FTR H_0

Note:* Indicatesstatistical significance at α = 10%; ** Indicates statistical significance at α = 5%;
*** Indicates statistical significance at α = 1%

Table 4B – Unit Root Results Presented By RATS – Model 4

Results of Augmented Dickey-Fuller Test of Null Hypothesis of
Existence of a Unit-Root Given by RATS
Model 4 - Estimation August 2007 - May 2017

Variable	Model Specification Selected	Test Statistic	Critical Value (α = 1%)	Critical Value (α = 5%)	Critical Value (α = 10%)	AIC Lag	Test Conclusion
JBSBTO	With Intercept	-4.608	-3.462	-2.875	-2.574	16	Significant at α = 1%
JMWING	With Intercept	0.061	-3.463	-2.875	-2.574	24	Unit Root
SMWING	With Intercept	-0.590	-3.463	-2.875	-2.574	24	Unit Root
TENDER	With Intercept	-2.672	-3.463	-2.875	-2.574	24	Significant at α = 10%