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An Empirical Analysis of Pricing in the U.S. Broiler and Pork Industries

Yuliya V. Bolotova

A former Assistant Professor of Agribusiness
Department of Agricultural Sciences
College of Agriculture, Forestry and Life Sciences
Clemson University
Clemson, SC 29634
E-mail: yuliyab@g.clemson.edu

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Abstract

During the recent decade a group of large meat processors in the U.S. broiler and pork industries implemented a series of production control practices at various stages of the broiler and pork supply chains. Direct and indirect buyers of broilers and pork filed class action antitrust lawsuits alleging that by implementing these production control practices the meat processors engaged in unlawful conspiracies with the purpose of fixing, increasing, and stabilizing prices of broilers and pork and thus violated Section 1 of the Sherman Act.

The research presented in the paper conducts an econometric analysis of price behavior in the U.S. broiler and pork industries during the periods of alleged price-fixing cartels and prior (more competitive) periods. The empirical evidence presented in the paper suggests the following. The wholesale pricing of pork by pork processors is consistent with an oligopoly pricing during both the pre-cartel and cartel periods. The retail pricing of pork by food retailers is consistent with a perfectly competitive pricing during both analyzed periods. The retail pricing of broilers by food retailers is consistent with a monopoly pricing during the pre-cartel period and with a monopoly and an oligopoly pricing during the cartel period.

Key words: Antitrust, broiler industry, cartels, margins, pork industry, price-fixing, seller market power, Sherman Act, supply restraints.

1. Introduction

During the recent decade a group of large meat processors in the U.S. broiler and pork industries used various production control practices, which affected the quantity of broilers and pork produced and marketed in the country. In particular, the meat processors implemented a series of production cuts at various stages of the broiler and pork supply chains. The meat processors used these practices to mitigate agricultural supply volatility and increases in agricultural input prices (i.e. feed prices), which led to the over-supply problem adversely affecting their profitability. These meat processors are vertically integrated companies, who make decisions affecting the quantity of broilers and pork produced at the farm (production) level through either a direct farm ownership or via production contracts.

Direct and indirect buyers of broilers and pork filed class action antitrust lawsuits alleging that the meat processors engaged in unlawful conspiracies with the purpose of fixing, increasing and stabilizing prices of broilers and pork paid by various participants in the broiler and pork supply chains (wholesalers, retailers and final consumers) (NBC News 2017, Chicago Tribune 2018, CNN business 2018, Feedstuffs 2018, The Washington Post 2018, USA TODAY 2018, National Hog Farmer 2018¹). The production control practices were alleged to be the primary method of implementing price-fixing conspiracies in these two industries, which is the type of conduct violating Section 1 of the Sherman Antitrust Act (1890).

At the beginning of 2021, the two largest broiler processors, Tyson Foods and Pilgrim's Pride Corporation (JBS SA) settled the broiler price-fixing lawsuit with direct buyers for \$80 million and \$75 million, respectively (Broiler Chicken Antitrust Litigation webpage). A few years earlier, a group of smaller broiler processors settled their lawsuits with direct buyers. In particular, the monetary settlements of Peco Foods, George's, Amick Farms, and Fieldale Farms Corporation totaled \$5.15 million, \$4.25 million, \$3.95 million, and \$2.25 million, respectively. At the end of 2020, one of the largest pork processors, JBS SA settled the pork lawsuit with direct buyers for \$24.5 million, and at the beginning of 2021 this company settled the pork lawsuit with indirect buyers for \$20 million (Pork Antitrust Litigation webpage; Devenyns 2021).

¹ The web-links to the broiler chicken and pork antitrust litigations' webpages are provided in the reference list. All relevant court documents are available on these webpages.

The research objective is to conduct an econometric analysis of price behavior in the U.S. broiler and pork industries during the periods of alleged price-fixing cartels and the prior (more competitive) periods. The wholesale and retail price behaviors are analyzed in the U.S. pork industry. The retail price behavior is analyzed in the U.S. broiler industry. Section 2 describes data and presents descriptive statistical analysis of prices and marketing margins in the U.S. broiler and pork supply chains during the two periods of interest. Section 3 presents economic model of a vertical price transmission used to develop econometric models of wholesale and retail price behaviors.

Section 4 describes econometric models and hypotheses. The focus of econometric analysis is on estimating cost pass-throughs, which can be used to distinguish between a perfectly competitive pricing and an imperfectly competitive pricing (the case of seller market power) of broiler and pork processors (wholesalers) and food retailers. Section 5 presents the results of econometric analysis, and it is followed by the conclusion. This paper extends the research presented in Bolotova (2019), which provides a background on the most recent competition issues in the U.S. broiler and pork industries.

2. Data and Descriptive Statistical Analysis

The empirical analysis is conducted using data available in the U.S. Department of Agriculture Economic Research Service (USDA ERS) publicly available databases. The farm, wholesale and retail values of pork and wholesale and retail prices of broilers are from *Historical Price Spread Data for Beef, Pork, Broilers* (USDA ERS 2021)². The farm, wholesale and retail values of pork used in the analysis are proxies for prices at the farm, wholesale and retail levels of the pork supply chain. The differences between these values are marketing margins in the pork supply chain: farm-to-wholesale margin, wholesale-to-retail margin, and farm-to-retail margin. The wholesale and

² USDA ERS collects prices corresponding to different levels of the pork supply chain (farm, processing plant (wholesale) and retail) and uses these prices to calculate farm value of pork, wholesale value of pork and retail value of pork and the differences between these values (price spreads): farm-to-wholesale price spread, wholesale-to-retail price spread and farm-to-retail price spread (Hahn 1991; 2002 and 2004). The farm and wholesale values are converted into a retail-weight equivalent. Therefore, price spreads are adjusted for the value of by-products and the weight loss, as animals move throughout the pork supply chain and are transformed into retail pork cuts. The price spreads are referred to as marketing margins in this paper.

retail prices of broiler chickens are composite prices, which are calculated as the weighted averages of whole chicken prices and prices of chicken parts³. The difference between retail price and wholesale price is wholesale-to-retail margin in the broiler supply chain.

Table 1 summarizes monthly averages and coefficients of variation for the farm, wholesale and retail values of pork, margins, and farm sector share during the two periods of interest. These are the period of alleged price-fixing cartel of pork processors, “cartel period” to be referred to in the paper (2009-2019), and the prior (more competitive) period, “pre-cartel period” to be referred to in the paper (1998-2008)⁴. This table also presents changes in the averages and coefficients of variation between these two periods. The pork values are used to calculate farm-to-wholesale margin, wholesale-to-retail margin, and farm sector share. Farm-to-wholesale margin is the difference between wholesale value of pork and farm value of pork; it includes wholesale (slaughtering and processing) costs and profit of pork processors (wholesalers). Wholesale-to-retail margin is the difference between retail value of pork and wholesale value of pork; it includes costs and profit of food retailers.

The pork farm-to-wholesale margin, wholesale-to-retail margin and farm sector share are expressed as a percentage of the retail value of pork⁵. The pork farm-to-wholesale margin is also expressed as a percentage of the wholesale value of pork. Figure 1 depicts monthly farm, wholesale and retail values of pork. Figure 2 depicts monthly farm sector share, farm-to-wholesale margin, and wholesale-to-retail margin, all expressed as a percentage of the retail value of pork.

³ Given that broiler processors own broiler chickens during the production process (at the farm stage), there are no farm-level prices in the broiler supply chain; consequently, there are no farm-to-wholesale margins. Broiler growers (farmers) do not acquire the ownership (title) of broiler chickens, when they raise them for broiler processors.

⁴ The year of 2009 distinguishes these two periods in the pork industry, because as it is stated in the complaints the allegedly anticompetitive (cartel) conduct of the pork processors began in 2009 and continued until “present” (while the original complaints (lawsuits) were filed in the court in 2018, the lawsuits were still pending as of December 2019). The period of 2009-2019 is selected as cartel period. The period of 1998-2008 is selected as pre-cartel period, because it has the same length as cartel period.

⁵ The sum of farm sector share, farm-to-wholesale margin, and wholesale-to-retail margin (all expressed as a percentage of the retail value) is equal to 100%.

Table 2 summarizes monthly averages and coefficients of variation for wholesale and retail prices of broilers, wholesale-to-retail margin, and wholesale sector share during the two periods of interest. These are the period of alleged price-fixing cartel of broiler processors, “cartel period” to be referred to in the paper (2008-2019), and the prior (more competitive) period, “pre-cartel period” to be referred to in the paper (1996-2007)⁶. This table also presents changes in the averages and coefficients of variation between these two periods. The wholesale and retail prices are used to calculate wholesale-to-retail margin and wholesale sector share. Wholesale-to-retail margin is the difference between retail price and wholesale price of broilers; it includes costs and profit of food retailers.

The broiler wholesale-to-retail margin and wholesale sector share are expressed as a percentage of the retail price of broilers⁷. Figure 3 depicts monthly wholesale and retail prices of broilers. Figure 4 depicts monthly wholesale sector share and wholesale-to-retail margin, both expressed as a percentage of the retail price of broilers.

2.1. U.S. pork industry (Table 1, Figures 1 and 2)

Pre-cartel period (1998-2008)

During pre-cartel period, the monthly average farm value, wholesale value and retail value of pork are \$0.77 per pound, \$1.14 per pound and \$2.70 per pound, respectively. The monthly average farm-to-wholesale margin and wholesale-to-retail margin are \$0.38 per pound and \$1.55 per pound, respectively. Expressed as a percentage of the retail value, the monthly average farm sector share, farm-to-wholesale margin, and wholesale-to-retail margin are 28.26%, 14.02% and 57.72%, respectively. Expressed as a percentage of the wholesale value, farm-to-wholesale margin is 33.59%.

⁶ The year of 2008 distinguishes these two periods in the broiler industry, because as it is stated in the complaints the allegedly anticompetitive (cartel) conduct of the broiler processors began in 2008 and continued until “present” (while the original complaints (lawsuits) were filed in the court in 2016, the lawsuits were still pending as of December 2019). The period of 2008-2019 is selected as cartel period. The period of 1996-2007 is selected as pre-cartel period, because it has the same length as cartel period.

⁷ The sum of wholesale sector share and wholesale-to-retail margin (both expressed as a percentage of the retail price) is equal to 100%.

Cartel period (2009-2019)

During cartel period, the monthly average values of pork and margins increase, but the monthly average farm sector share decreases. The rate of the farm value increase (24.2%) is smaller than the rate of the wholesale and retail values' increases (30.6% and 33.4%, respectively). The rate of the farm-to-wholesale margin increase is higher than the rate of the wholesale-to-retail margin increase. The farm-to-wholesale margin measured in monetary units increases by 43.5%. This margin measured as a percentage of the wholesale value increases by 9.1%, and this margin measured as a percentage of the retail value increases by 6.8%. The wholesale-to-retail margin measured in monetary units increases by 35.4%, and this margin measured as a percentage of the retail value increases by 1.4%. The farm sector share measured as a percentage of the retail value decreases by 6.2%.

During cartel period, the monthly average farm value, wholesale value and retail value of pork are \$0.95 per pound, \$1.49 per pound and \$3.60 per pound, respectively. The monthly average farm-to-wholesale margin and wholesale-to-retail margin are \$0.54 per pound and \$2.11 per pound, respectively. Expressed as a percentage of the retail value, the monthly average farm sector share, farm-to-wholesale margin, and wholesale-to-retail margin are 26.51%, 14.98% and 58.51%, respectively. Expressed as a percentage of the wholesale value, farm-to-wholesale margin is 36.64%.

While the wholesale value of pork and farm-to-wholesale margin increase in cartel period, as compared to pre-cartel period, these increases are relatively small in magnitude. In addition, the magnitude of the farm-to-wholesale margin is the smallest, as compared to the farm sector share and the wholesale-to-retail margin during both analyzed periods. The farm-to-wholesale margin measured as a percentage of the retail value increased from 14.02% in pre-cartel period to 14.98% in cartel period, or by 1.0%-point (6.8%). The wholesale-to-retail margin measured as a percentage of the retail value increased from 57.72% in pre-cartel period to 58.51% in cartel period, or by 0.8%-points (1.4%). The farm sector share decreased from 28.26% in pre-cartel period to 26.51% in cartel period, or by 1.8%-points (6.2%). The farm-to-wholesale margin measured as a percentage of the wholesale value increased from 33.59% in pre-cartel period to 36.64% in cartel period, or by 3.1%-points (9.1%).

As indicated by changes in the coefficients of variation, the farm, wholesale and retail values of pork, farm-to-wholesale margin, wholesale-to-retail margin and farm sector share are more volatile in cartel period, as compared to pre-cartel period.

2.2. U.S. broiler industry (Table 2, Figures 3 and 4)

Pre-cartel period (1996-2007)

During pre-cartel period, the monthly average wholesale price and retail price of broilers are \$0.63 per pound and \$1.60 per pound, respectively. The monthly average wholesale-to-retail margin is \$0.96 per pound. Expressed as a percentage of the retail price, the monthly average wholesale sector share and wholesale-to-retail margin are 39.61% and 60.39%, respectively.

Cartel period (2008-2019)

During cartel period, the monthly average prices of broilers, wholesale-to-retail margin measured in monetary units and wholesale sector share increase, but the monthly average wholesale-to-retail margin measured as a percentage of the retail price decreases. The rate of the wholesale price increase (24.6%) is higher than the rate of the retail price increase (16.8%). The wholesale-to-retail margin measured in monetary units increases by 11.6%. This margin measured as a percentage of the retail price decreases by 4.4%. The wholesale sector share measured as a percentage of the retail price increases by 6.7%.

During cartel period, the monthly average wholesale price and retail price of broilers are \$0.79 per pound and \$1.86 per pound, respectively. The monthly average wholesale-to-retail margin is \$1.08 per pound. Expressed as a percentage of the retail price, the monthly average wholesale sector share and wholesale-to-retail margin are 42.28% and 57.72%, respectively.

As indicated by changes in the coefficients of variation, the wholesale and retail prices of broilers, wholesale-to-retail margin, and wholesale sector share are less volatile in cartel period, as compared to pre-cartel period.

3. Economic Model

The economic model of a vertical price transmission is a relevant theoretical framework used as a foundation for econometric analysis of wholesale and retail price behaviors. In the case of the U.S. pork industry, the focus is on two price relationships: the relationship between wholesale price of pork (a revenue element for pork processors) and farm price of pork (a cost element for pork

processors), and the relationship between retail price of pork (a revenue element for food retailers) and wholesale price of pork (a cost element for food retailers). In the case of the U.S. broiler industry, the focus is on one price relationship: the relationship between retail price of broilers (a revenue element for food retailers) and wholesale price of broilers (a cost element for food retailers).

The vertical price transmission mechanism reflects cost pass-through, which magnitude can be used to distinguish between a perfectly competitive pricing and an imperfectly competitive pricing (seller market power: oligopoly and monopoly) and to characterize pricing practices (methods) used by broiler and pork processors (wholesalers) and food retailers⁸.

Equation [1] represents a linear price transmission process. The output price P *output* (downstream price) is specified as a linear function of the input price P *input* (upstream price).

$$[1] P \text{ output} = a + b * P \text{ input}.$$

Three price transmission processes are analyzed in this research: farm-to-wholesale price transmission process represented by equation [1.1] and wholesale-to-retail price transmission process represented by equation [1.2] in the case of the U.S. pork industry, and wholesale-to-retail price transmission process represented by equation [1.3] in the case of the U.S. broiler industry.

$$[1.1] \text{ Wholesale Pork Price} = a_1 + b_1 * \text{Farm Pork Price}.$$

$$[1.2] \text{ Retail Pork Price} = a_2 + b_2 * \text{Wholesale Pork Price}.$$

$$[1.3] \text{ Retail Broiler Price} = a_3 + b_3 * \text{Wholesale Broiler Price}.$$

In equation [1], a is a non-negative constant, which is also referred to as a fixed absolute markup, and b is a vertical price transmission coefficient, which is also referred to as a cost pass-through (CPT). The CPT indicates a \$ per unit increase (decrease) in the output price, which follows a \$1 per unit increase (decrease) in the input price. CPT in equation [1.1] is pork farm-to-wholesale price transmission coefficient (b_1). CPT in equation [1.2] is pork wholesale-to-retail price transmission coefficient (b_2). CPT in equation [1.3] is broiler wholesale-to-retail price transmission coefficient (b_3).

⁸ A comprehensive discussion of cost pass-through in light of imperfectly competitive pricing and antitrust issues is presented in Harris and Sullivan (1979), Cotterill (1998), Cotterill et al (2001), Kosicki and Cahill (2006), and RBB Economics (2014). The types of wholesale pricing methods are discussed in George and King (1971).

Given that marketing margin (*Margin*) is the difference between output price and input price:

$$[2] \text{Margin} = P_{\text{output}} - P_{\text{input}},$$

substituting [1] into [2] yields the identity for marketing margin:

$$[3] \text{Margin} = a + (b-1)*P_{\text{input}}.$$

The magnitude of the coefficients in equations [1] and [3] provides evidence on pricing methods used by wholesalers and retailers. The magnitude of $b=1$ (complete cost pass-through) and $a>0$ would reflect a fixed absolute markup pricing method consistent with perfect competition characterized by a “sticky” margin (*Margin* = a). The magnitude of $b<1$ would reflect an imperfectly competitive pricing (seller market power: oligopoly and monopoly).

If a profit-maximizing monopolist operates in a market environment with linear demand and constant marginal cost, the magnitude of b is equal to 0.5 (incomplete cost pass-through). The first-order profit-maximization condition for this monopolist can be rearranged to express its output price as a function of marginal cost (input price): $P = 0.5 + 0.5*MC$. The constant a is non-negative in this case. A profit-maximizing oligopoly in a similar market environment would yield the magnitude of b in the range from 0.5 (monopoly) to 1 (perfect competition). The output price stabilization method is consistent with pricing predicted by these economic models.

4. Econometric Models and Hypotheses

The objective of the econometric analysis is to evaluate whether there are changes in the wholesale and retail price behaviors and associated price transmission processes in the U.S. pork supply chain between pre-cartel period (1998-2008) and cartel period (2009-2019), and whether there are changes in the retail price behavior and associated price transmission process in the U.S. broiler supply chain between pre-cartel period (1996-2007) and cartel period (2008-2019). The focus is on evaluating the magnitude and statistical significance of the fixed absolute markups (FAMs) and cost pass-throughs (CPTs) in the two analyzed periods as well as changes in FAMs and CPTs between these two periods.

The econometric model of wholesale pork price behavior is represented by equation [4]. The econometric model of retail pork price behavior is represented by equation [5]. The

econometric model of retail broiler price behavior is represented by equation [6]. All econometric models are specified as linear regression models⁹.

$$[4] \quad WPP_t = \alpha_1 + \beta_1 FPP_t + \mu_1 C_t + \gamma_1 FPP_t C_t + \theta_1 M_t + \varepsilon_{t1}$$

In equation [4], WPP_t and FPP_t are wholesale value of pork and farm value of pork, respectively, in month t . Both values are measured in cents per pound. C_t is a binary variable (intercept shifter); it is equal to one, if a wholesale value observation belongs to cartel period (2009-2019), and it is equal to zero, if a wholesale value observation belongs to pre-cartel period (1998-2008). The reference group is represented by wholesale value observations belonging to pre-cartel period. $FPP_t C_t$ is the interaction effect of the farm value and cartel binary variable (slope shifter). M_t is a set of monthly binary variables. ε_{t1} is the error term.

$$[5] \quad RPP_t = \alpha_2 + \beta_2 WPP_t + \mu_2 C_t + \gamma_2 WPP_t C_t + \theta_2 M_t + \varepsilon_{t2}$$

In equation [5], RPP_t and WPP_t are retail value of pork and wholesale value of pork, respectively, in month t . Both values are measured in cents per pound. C_t is a binary variable (intercept shifter); it is equal to one, if a retail value observation belongs to cartel period (2009-2019), and it is equal to zero, if a retail value observation belongs to pre-cartel period (1998-2008). The reference group is represented by retail value observations belonging to pre-cartel period. $WPP_t C_t$ is the interaction effect of the wholesale value and cartel binary variable (slope shifter). M_t is a set of monthly binary variables. ε_{t2} is the error term.

$$[6] \quad RBP_t = \alpha_3 + \beta_3 WBP_t + \mu_3 C_t + \gamma_3 WBP_t C_t + \theta_3 M_t + \varepsilon_{t3}$$

In equation [6], RBP_t and WBP_t are retail price of broilers and wholesale price of broilers, respectively, in month t . Both prices are measured in cents per pound. C_t is a binary variable (intercept shifter); it is equal to one, if a retail price observation belongs to cartel period (2008-2019), and it is equal to zero, if a retail price observation belongs to pre-cartel period (1996-2007). The reference group is represented by retail price observations belonging to pre-cartel period.

⁹ During the preliminary stage of the econometric analysis, alternative number of lagged price variables were included as independent variables in the econometric models. The lagged prices included as independent variables were not statistically significant from zero. Therefore, these lagged price variables are not included in the final specifications of the econometric models.

$WBP_t C_t$, is the interaction effect of the wholesale price and cartel binary variable (slope shifter). \mathbf{M}_t is a set of monthly binary variables. ε_{t3} is the error term.

Each econometric model for the U.S. pork industry has 264 observations. The econometric model for the U.S. broiler industry has 288 observations. The econometric models are estimated using the Ordinary Least Squares (OLS) estimation procedure.

Table I presented below provides the interpretation of constants and coefficients in the econometric models representing the price functions. In light of the theoretical framework, the constants are fixed absolute markups (FAM), and the coefficients are cost pass-throughs (CPT).

Table I. Interpretation of Constants “Fixed Absolute Markups” (FAM) and Coefficients “Cost Pass-Throughs” (CPT) in the Pork and Broiler Price Functions:
Equations [4], [5] and [6].

Pre-cartel period	Cartel period
U.S. Pork Industry	
<i>Wholesale price function (equation [4]):</i>	
<i>CPT is farm-to-wholesale price transmission coefficient</i>	
α_1 is FAM	$(\alpha_1 + \mu_1)$ is FAM
	μ_1 is the difference in FAM between the cartel and pre-cartel periods
β_1 is current month CPT	$(\beta_1 + \gamma_1)$ is current month CPT
	γ_1 is the difference in current month CPT between the cartel and pre-cartel periods
<i>Retail price function (equation [5]):</i>	
<i>CPT is wholesale-to-retail price transmission coefficient</i>	
α_2 is FAM	$(\alpha_2 + \mu_2)$ is FAM
	μ_2 is the difference in FAM between the cartel and pre-cartel periods
β_2 is current month CPT	$(\beta_2 + \gamma_2)$ is current month CPT
	γ_2 is the difference in CPT between the cartel and pre-cartel periods
U.S. Broiler Industry	
<i>Retail price function (equation [6]):</i>	
<i>CPT is wholesale-to-retail price transmission coefficient</i>	
α_3 is FAM	$(\alpha_3 + \mu_3)$ is FAM
	μ_3 is the difference in FAM between the cartel and pre-cartel periods
β_3 is current month CPT	$(\beta_3 + \gamma_3)$ is current month CPT
	γ_3 is the difference in CPT between the cartel and pre-cartel periods

Table II presented below summarizes the null and alternative hypotheses for T-tests on the magnitude of constants (fixed absolute markups) and coefficients (cost pass-throughs) during the analyzed periods.

Table II. T-Tests on the Magnitude of Fixed Absolute Markups (FAM) and Cost Pass-Throughs (CPT): The Null and Alternative Hypotheses.

<i>Hypotheses on the magnitude of fixed absolute markup</i> Ho: FAM = 0 and Ha: FAM > 0
<i>Hypotheses on the CPT magnitude: a perfectly competitive pricing case</i> Ho is perfectly competitive pricing (complete CPT) Ha is imperfectly competitive pricing (incomplete CPT): monopoly or oligopoly in a market with linear demand and constant marginal cost Ho: CPT = 1 and Ha: CPT < 1
<i>Hypotheses on the CPT magnitude: an imperfectly competitive pricing case #1</i> Ho is monopoly pricing in a market with linear demand and constant marginal cost (incomplete CPT) Ha is oligopoly pricing in a market with linear demand and constant marginal cost (incomplete CPT) Ho: CPT = 0.50 and Ha: CPT > 0.50
<i>Hypotheses on the CPT magnitude: an imperfectly competitive pricing case #2</i> Ho is oligopoly pricing in a market with linear demand and constant marginal cost (incomplete CPT) Ha is monopoly pricing in a market with linear demand and constant marginal cost (incomplete CPT) Ho: CPT = 0.75* and Ha: CPT < 0.75

* In a market with linear demand and constant marginal cost, the oligopoly CPT is greater than 0.5 (monopoly) and smaller than 1 (perfect competition). 0.75, which is a midpoint of this range, is used for the purpose of testing CPT consistent with oligopoly pricing.

5. Estimation Results

5.1. U.S. Pork Industry

5.1.1. Wholesale price behavior and farm-to-wholesale price transmission (Tables 3 and 6)

Table 3 summarizes the OLS estimation results and the outcomes of T-tests on statistical significance of fixed absolute markups and cost pass-throughs. Table 6 summarizes the outcomes of additional T-tests on the type of wholesale pork pricing (perfectly competitive pricing or imperfectly competitive pricing) and pricing methods used by pork processors (wholesalers) during the two analyzed periods of interest.

The variation in the explanatory variables (farm value, cartel binary variable, the interaction effect of the farm value and cartel binary variable, and a set of monthly binary

variables) explains almost 90% of the variation in the wholesale pork value. The estimated coefficients have expected signs and magnitude, and many of them are statistically significant from zero.

Pre-cartel period (1998-2008)

The fixed absolute markup is 44.51 cents per pound, and it is statistically greater than zero. The cost pass-through (CPT) is 0.91. The CPT magnitude suggests that an increase (decrease) in farm value of pork by 1 cent per pound causes wholesale value of pork to increase (decrease) by 0.91 cents per pound. Alternatively, an increase (decrease) in farm value of pork by \$1.00 per pound causes wholesale value of pork to increase (decrease) by \$0.91 per pound. The pre-cartel period cost pass-through (0.91) is incomplete. The null hypothesis of a perfectly competitive pricing $CPT=1$ is rejected in favor of alternative hypothesis $CPT<1$ reflecting oligopoly pricing. At the same time the null hypothesis $CPT=0.50$ reflecting monopoly pricing is rejected in favor of alternative hypothesis $CPT>0.50$ reflecting oligopoly pricing. The wholesale pricing of pork by pork processors (wholesalers) during pre-cartel period is consistent with oligopoly pricing in a market with linear demand and constant marginal cost. This type of pricing reflects a wholesale price stabilization method used by pork processors (wholesalers).

Cartel period (2009-2019)

During cartel period, as compared to pre-cartel period, fixed absolute markup increases, and cost pass-through decreases. The estimated increase in fixed absolute markup is statistically significant from zero, and the estimated decrease in cost pass-through is not statistically significant from zero. During cartel period, fixed absolute markup is 68.31 cents per pound, and it is statistically greater than zero. The cost pass-through is 0.85. The CPT magnitude suggests that an increase (decrease) in farm value of pork by 1 cent per pound causes wholesale value of pork to increase (decrease) by 0.85 cents per pound. Alternatively, an increase (decrease) in farm value of pork by \$1.00 per pound causes wholesale value of pork to increase (decrease) by \$0.85 per pound.

The cartel period cost pass-through (0.85) is incomplete. The null hypothesis of a perfectly competitive pricing $CPT=1$ is rejected in favor of alternative hypothesis of imperfectly competitive pricing $CPT<1$. Furthermore, the null hypothesis of $CPT=0.75$ reflecting oligopoly pricing fails to be rejected. Consequently, wholesale pork pricing during cartel period is consistent with oligopoly

pricing in a market with linear demand and constant marginal cost. This type of pricing reflects a wholesale price stabilization method used by pork processors (wholesalers).

5.1.2. Retail price behavior and wholesale-to-retail price transmission (Tables 4 and 6)

Table 4 summarizes the OLS estimation results and the outcomes of T-tests on statistical significance of fixed absolute markups and cost pass-throughs. Table 6 summarizes the outcomes of additional T-tests on the type of retail pork pricing (perfectly competitive pricing or imperfectly competitive pricing) and pricing methods used by food retailers during the two analyzed periods of interest.

The variation in the explanatory variables (wholesale value, cartel binary variable, the interaction effect of the wholesale value and cartel binary variable, and a set of monthly binary variables) explains 86% of the variation in the retail pork value. The estimated coefficients have expected signs and magnitude, and many of them are statistically significant from zero.

Pre-cartel period (1998-2008)

The fixed absolute markup is 143.95 cents per pound, and it is statistically greater than zero. The cost pass-through (CPT) is 1.10. The CPT magnitude suggests that an increase (decrease) in wholesale value of pork by 1 cent per pound causes retail value of pork to increase (decrease) by 1.10 cents per pound. Alternatively, an increase (decrease) in wholesale value of pork by \$1.00 per pound causes retail value of pork to increase (decrease) by \$1.10 per pound. The pre-cartel period cost pass-through (1.10) is complete. The null hypothesis of a perfectly competitive pricing CPT=1 fails to be rejected. The retail pork pricing by food retailers during pre-cartel period is consistent with a perfectly competitive pricing. This type of pricing reflects a fixed absolute markup pricing method used by food retailers.

Cartel period (2009-2019)

During cartel period, as compared to pre-cartel period, fixed absolute markup increases, and cost pass-through decreases. The estimated increase in fixed absolute markup is statistically significant from zero, and the estimated decrease in cost pass-through is not statistically significant from zero. During cartel period, fixed absolute markup is 204.62 cents per pound, and it is statistically greater than zero. The cost pass-through is 1.04. The CPT magnitude suggests that an increase (decrease) in wholesale value of pork by 1 cent per pound causes retail value of pork to increase (decrease)

by 1.04 cents per pound. Alternatively, an increase (decrease) in wholesale value of pork by \$1.00 per pound causes retail value of pork to increase (decrease) by \$1.04 per pound. The cartel period cost pass-through (1.04) is complete. The null hypothesis of a perfectly competitive pricing CPT=1 fails to be rejected. The retail pork pricing during cartel period is consistent with a perfectly competitive pricing. This type of pricing reflects a fixed absolute markup pricing method used by food retailers.

5.2. U.S. Broiler Industry

5.2.1. Retail price behavior and wholesale-to-retail price transmission (Tables 5 and 7)

Table 5 summarizes the OLS estimation results and the outcomes of T-tests on statistical significance of fixed absolute markups and cost pass-throughs. Table 7 summarizes the outcomes of additional T-tests on the type of retail pricing (perfectly competitive pricing or imperfectly competitive pricing) and pricing methods used by food retailers during the two analyzed periods of interest.

The variation in the explanatory variables (wholesale price, cartel binary variable, the interaction effect of the wholesale price and cartel binary variable, and a set of monthly binary variables) explains 80% of the variation in the retail price of broilers. The estimated coefficients have expected signs and magnitude, and many of them are statistically significant from zero.

Pre-cartel period (1996-2007)

The fixed absolute markup is 131.22 cents per pound, and it is statistically greater than zero. The cost pass-through (CPT) is 0.44. The CPT magnitude suggests that an increase (decrease) in wholesale price of broilers by 1 cent per pound causes retail price of broilers to increase (decrease) by 0.44 cents per pound. Alternatively, an increase (decrease) in wholesale price of broilers by \$1.00 per pound causes retail price of broiler to increase (decrease) by \$0.44 per pound. The pre-cartel period cost pass-through (0.44) is incomplete. The null hypothesis of a monopoly pricing CPT=0.50 fails to be rejected. The retail pricing of broilers by food retailers during pre-cartel period is consistent with monopoly pricing in a market with linear demand and constant marginal cost. This type of pricing reflects a retail price stabilization method used by food retailers.

Cartel period (2008-2019)

During cartel period, as compared to pre-cartel period, both fixed absolute markup and cost pass-through increase. The estimated increase in fixed absolute markup is not statistically significant from zero, and the estimated increase in cost pass-through is statistically significant from zero. During cartel period, fixed absolute markup is 136.08 cents per pound, and it is statistically greater than zero. The cost pass-through is 0.63. The CPT magnitude suggests that an increase (decrease) in wholesale price of broilers by 1 cent per pound causes retail price of broilers to increase (decrease) by 0.63 cents per pound. Alternatively, an increase (decrease) in wholesale price of broilers by \$1.00 per pound causes retail price of broilers to increase (decrease) by \$0.63 per pound.

The cartel period cost pass-through (0.63) is incomplete. The null hypothesis of CPT=0.75 reflecting oligopoly pricing fails to be rejected. Furthermore, the null hypothesis of CPT=0.50 reflecting monopoly pricing fails to be rejected as well. Consequently, retail pricing of broilers during cartel period is consistent with monopoly and oligopoly pricing in a market with linear demand and constant marginal cost. This type of pricing reflects a retail price stabilization method used by food retailers.

6. Conclusion

The research presented in the paper conducts an econometric analysis of wholesale and retail price behaviors in the U.S. pork industry and retail price behavior in the U.S. broiler industry during the periods of alleged price-fixing cartels of the largest pork and broiler processors and prior (more competitive) periods. There is empirical evidence indicating somewhat minor changes in the wholesale and retail price behaviors of pork and in the retail price behavior of broilers during these two periods.

The wholesale pricing of pork by pork processors is consistent with oligopoly pricing in a market with linear demand and constant marginal cost during both the pre-cartel and cartel periods. While there was an increase in the degree of oligopoly power of pork processors in cartel period, as compared to pre-cartel period (reflected in a decrease in cost pass-through), this increase in oligopoly power was not statistically significant. Pork processors used a wholesale price stabilization method during both analyzed periods. The retail pricing of pork by food retailers is

consistent with a perfectly competitive pricing during both the pre-cartel and cartel periods. Food retailers used a fixed absolute markup pricing method during both periods of interest.

The retail pricing of broilers by food retailers is consistent with monopoly pricing in a market with linear demand and constant marginal cost during pre-cartel period. The retail pricing of broilers by food retailers is consistent with both monopoly and oligopoly pricing in a market with linear demand and constant marginal cost during cartel period. There was a decrease in the degree of seller market power of food retailers in cartel period, as compared to pre-cartel period (reflected in a statistically significant increase in cost pass-through).

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Table 1. U.S. Pork Industry Farm, Wholesale and Retail Values, Farm Sector Share, Farm-to-Wholesale and Wholesale-to-Retail Margins: Descriptive Statistics (1998-2019).

Variable/Formula	Unit of measurement	Pre-cartel period (1998-2008)		Cartel period (2009-2019)		Change in cartel period, relative to pre-cartel period	
		Average	CV	Average	CV	Average (%)	CV (%)
Pork Farm Value (FP)	Cents per pound	76.50	0.19	94.99	0.22	18.5 (24.2)	0.03 (15.1)
Pork Wholesale Value (WP)	Cents per pound	114.21	0.12	149.12	0.14	34.9 (30.6)	0.02 (20.8)
Pork Retail Value (RP)	Cents per pound	269.68	0.06	359.70	0.09	90.0 (33.4)	0.03 (46.2)
Pork Farm-to-Wholesale Margin: WP-FP	Cents per pound	37.71	0.11	54.13	0.22	16.4 (43.5)	0.11 (99.8)
Pork Farm-to-Wholesale Margin: [(WP-FP)/WP]*100%	% of wholesale value	33.59	0.19	36.64	0.22	3.1 (9.1)	0.03 (16.2)
Pork Farm-to-Wholesale Margin: [(WP-FP)/RP]*100%	% of retail value	14.02	0.12	14.98	0.18	1.0 (6.8)	0.06 (47.2)
Pork Wholesale-to-Retail Margin: RP-WP	Cents per pound	155.47	0.07	210.58	0.13	55.1 (35.4)	0.06 (78.1)
Pork Wholesale-to-Retail Margin: [(RP-WP)/RP]*100%	% of retail value	57.72	0.06	58.51	0.08	0.8 (1.4)	0.02 (33.8)
Pork Farm Sector Share: [FP/RP]*100%	% of retail value	28.26	0.16	26.51	0.21	-1.8 (-6.2)	0.05 (29.9)

Number of observations is 132 in each of the analyzed periods. CV is the coefficient of variation (=standard deviation/average).

The averages and coefficients of variation are calculated by the author using farm, wholesale and retail values of pork reported in USDA ERS (2021).

Table 2. U.S. Broiler Industry Wholesale and Retail Prices, Wholesale Sector Share and Wholesale-to-Retail Margin: Descriptive Statistics (1996-2019).

Variable/Formula	Unit of measurement	Pre-cartel period (1996-2007)		Cartel period (2008-2019)		Change in cartel period, relative to pre-cartel period	
		Average	CV	Average	CV	Average (%)	CV (%)
Broiler Wholesale Price (WP)	Cents per pound	63.23	0.15	78.78	0.10	15.6 (24.6)	-0.04 (-28.7)
Broiler Retail Price (RP)	Cents per pound	159.54	0.05	186.29	0.05	26.8 (16.8)	-0.01 (-10.8)
Broiler Wholesale-to-Retail Margin: RP-WP	Cents per pound	96.31	0.10	107.51	0.08	11.2 (11.6)	-0.02 (-19.1)
Broiler Wholesale-to-Retail Margin: [(RP-WP)/RP]*100%	% of retail price	60.39	0.08	57.72	0.06	-2.7 (-4.4)	-0.02 (-23.7)
Broiler Wholesale Sector Share: [WP/RP]*100%	% of retail price	39.61	0.13	42.28	0.09	2.7 (6.7)	-0.04 (-31.7)

Number of observations is 144 in each of the analyzed periods. CV is the coefficient of variation (=standard deviation/average).

The averages and coefficients of variation are calculated by the author using wholesale and retail prices of broilers reported in USDA ERS (2021).

Table 3. U.S. Pork Industry: Wholesale Pork Price Behavior (1998-2019):
The OLS Estimation Results.

Variable	Coefficient	Estimated Coefficient	T-ratio
FPP _t	β_1	0.91*	24.51
C _t	μ_1	23.79*	3.35
FPP _t C _t	γ_1	-0.06	-0.83
February		-2.63 ^a	-1.58
March		-1.57	-0.64
April		-1.25	-0.47
May		-3.00	-1.13
June		-2.15	-0.80
July		-1.07	-0.38
August		0.01	0.004
September		2.69	1.15
October		2.73	1.14
November		4.47*	1.76
December		3.44*	1.84
Constant	α_1	44.51*	15.68
R2		0.89	
D-W Statistic ¹		0.28	
F-test (seasonality) p-value		0.1604	
<i>Pre-cartel period (1998-2008)</i>			
Fixed absolute markup	α_1	44.51*	15.68
Cost pass-through	β_1	0.91*	24.51
<i>Change between pre-cartel period and cartel period</i>			
Fixed absolute markup	μ_1	23.79*	3.35
Cost pass-through	γ_1	-0.06	-0.83
<i>Cartel period (2009-2019)</i>			
Fixed absolute markup	$\alpha_1+\mu_1$	68.31*	9.93
Cost pass-through	$\beta_1+\gamma_1$	0.85*	12.57

¹ T-ratios are calculated using autocorrelation-adjusted standard errors based on Newey-West approach.

* The estimated coefficient (EC) is statistically significant from zero at the 10% significant level using a two-tailed T-test. Ho: EC=0, and Ha: EC \neq 0; the T statistic rejection regions are $(-\infty; -1.64]$ and $[1.64; +\infty)$.

^a The estimated coefficient (EC) is statistically significant from zero at the 10% significance level using a one-tailed T test. Ho: EC=0, and Ha: EC<0; the T statistic rejection region is $(-\infty; -1.28]$.

The number of observations is 264.

Table 4. U.S. Pork Industry: *Retail* Pork Price Behavior (1998-2019):
The OLS Estimation Results.

Variable	Coefficient	Estimated coefficient	T-ratio
WPP _t	β_2	1.10*	11.90
C _t	μ_2	60.67*	2.50
WPP _t C _t	γ_2	-0.06	-0.38
February		0.47	0.10
March		-0.34	-0.05
April		-3.22	-0.50
May		-6.66	-1.11
June		-8.47 ^a	-1.49
July		-6.81	-1.20
August		-0.11	-0.02
September		6.58	1.03
October		6.06	0.98
November		6.53	1.13
December		4.59	0.94
Constant	α_2	143.95*	13.51
R2		0.86	
D-W Statistic ¹		0.26	
F-test (seasonality) p-value		0.3222	
<i>Pre-cartel period (1998-2008)</i>			
Fixed absolute markup	α_2	143.95*	13.51
Cost pass-through	β_2	1.10*	11.90
<i>Change between pre-cartel period and cartel period</i>			
Fixed absolute markup	μ_2	60.67*	2.50
Cost pass-through	γ_2	-0.06	-0.38
<i>Cartel period (2009-2019)</i>			
Fixed absolute markup	$\alpha_2+\mu_2$	204.62*	9.20
Cost pass-through	$\beta_2+\gamma_2$	1.04*	7.54

¹ T-ratios are calculated using autocorrelation-adjusted standard errors based on Newey-West approach.

* The estimated coefficient (EC) is statistically significant from zero at the 10% significant level using a two-tailed T-test. Ho: EC=0, and Ha: EC \neq 0; the T statistic rejection regions are $(-\infty; -1.64]$ and $[1.64; +\infty)$.

^a The estimated coefficient (EC) is statistically significant from zero at the 10% significance level using a one-tailed T test. Ho: EC=0, and Ha: EC<0; the T statistic rejection region is $(-\infty; -1.28]$.

The number of observations is 264.

Table 5. U.S. Broiler Industry: *Retail* Broiler Price Behavior (1996-2019):
The OLS Estimation Results.

Variable	Coefficient	Estimated coefficient	T-ratio
WBP _t	β_3	0.44*	6.34
C _t	μ_3	4.86	0.51
WBP _t C _t	γ_3	0.19 ^b	1.53
February		-0.79	-0.53
March		-1.46	-0.70
April		-0.73	-0.35
May		-2.68 ^a	-1.42
June		-1.99	-1.05
July		-1.50	-0.75
August		-0.10	-0.05
September		0.82	0.40
October		3.25 ^b	1.49
November		4.14*	1.89
December		3.74*	2.17
Constant	α_3	131.22*	29.23
R2		0.80	
D-W Statistic ¹		0.26	
F-test (seasonality) p-value		0.0467	
<i>Pre-cartel period (1996-2007)</i>			
Fixed absolute markup	α_3	131.22*	29.23
Cost pass-through	β_3	0.44*	6.34
<i>Change between pre-cartel period and cartel period</i>			
Fixed absolute markup	μ_3	4.86	0.51
Cost pass-through	γ_3	0.19 ^b	1.53
<i>Cartel period (2008-2019)</i>			
Fixed absolute markup	$\alpha_3+\mu_3$	136.08*	15.95
Cost pass-through	$\beta_3+\gamma_3$	0.63*	6.19

¹ T-ratios are calculated using autocorrelation-adjusted standard errors based on Newey-West approach.

* The estimated coefficient (EC) is statistically significant from zero at the 10% significant level using a two-tailed T-test. Ho: EC=0, and Ha: EC \neq 0; the T statistic rejection regions are $(-\infty; -1.64]$ and $[1.64; +\infty)$.

^a The estimated coefficient (EC) is statistically significant from zero at the 10% significance level using a one-tailed T test. Ho: EC=0, and Ha: EC<0; the T statistic rejection region is $(-\infty; -1.28]$.

^b The estimated coefficient (EC) is statistically significant from zero at the 10% significance level using a one-tailed T test. Ho: EC=0, and Ha: EC>0; the T statistic rejection region is $[1.28; +\infty)$.

The number of observations is 288.

Table 6. U.S. Pork Industry: Wholesale and Retail Pricing of Pork (1998-2019).

	Wholesale pork pricing	Retail pork pricing
Pre-cartel period (1998-2008)		
Fixed Absolute Markup	44.51 0.91 Ho: CPT = 1 is rejected in favor of Ha: CPT < 1 (T statistic = -2.45) Ho: CPT = 0.50 is rejected in favor of Ha: CPT > 0.50 (T statistic = 11.03)	143.95 1.10 Ho: CPT = 1 fails to be rejected (T statistic = 1.10)
Cost Pass Through (CPT)	Oligopoly pricing [linear demand, constant marginal cost]	Perfectly competitive pricing
Pricing method	Wholesale price stabilization	Fixed absolute markup
Cartel period (2009-2019)		
Fixed Absolute Markup	68.31 0.85 Ho: CPT = 1 is rejected in favor of Ha: CPT < 1 (T statistic = -2.23) Ho: CPT = 0.75 fails to be rejected (T statistic = 1.47)	204.62 1.04 Ho: CPT = 1 fails to be rejected (T statistic = 0.30)
Cost Pass Through (CPT)	Oligopoly pricing [linear demand, constant marginal cost]	Perfectly competitive pricing
Economic model	Wholesale price stabilization	Fixed absolute markup
Pricing method		

The null and alternative hypotheses on the types of pricing methods are explained in Table II.

T-statistic cut-off value used to conduct T-tests presented in this table is |1.64| (one-tailed T-test and 5% significance level).

The fixed absolute markups and cost pass-throughs are from Tables 3 and 4.

The fixed absolute markups are statistically greater than zero (Tables 3 and 4).

Table 7. U.S. Broiler Industry: Retail Pricing of Broilers (1996-2019).

Retail broiler pricing	
Pre-cartel period (1996-2007)	
Fixed Absolute Markup	131.22 0.44
Cost Pass Through (CPT)	Ho: CPT = 0.50 fails to be rejected (T statistic = -0.75)
Economic model	Monopoly pricing [linear demand, constant marginal cost]
Pricing method	Retail price stabilization
Cartel period (2008-2019)	
Fixed Absolute Markup	136.08 0.63
Cost Pass Through (CPT)	Ho: CPT = 0.50 fails to be rejected (T statistic = 1.31) Ho: CPT = 0.75 fails to be rejected (T statistic = -1.13)
Economic model	Monopoly/Oligopoly pricing [linear demand, constant marginal cost]
Pricing method	Retail price stabilization

The null and alternative hypotheses on the types of pricing methods are explained in Table II. T-statistic cut-off value used to conduct T-tests presented in this table is |1.64| (one-tailed T-test and 5% significance level).

The fixed absolute markups and cost pass-throughs are from Table 5.

The fixed absolute markups are statistically greater than zero (Table 5).

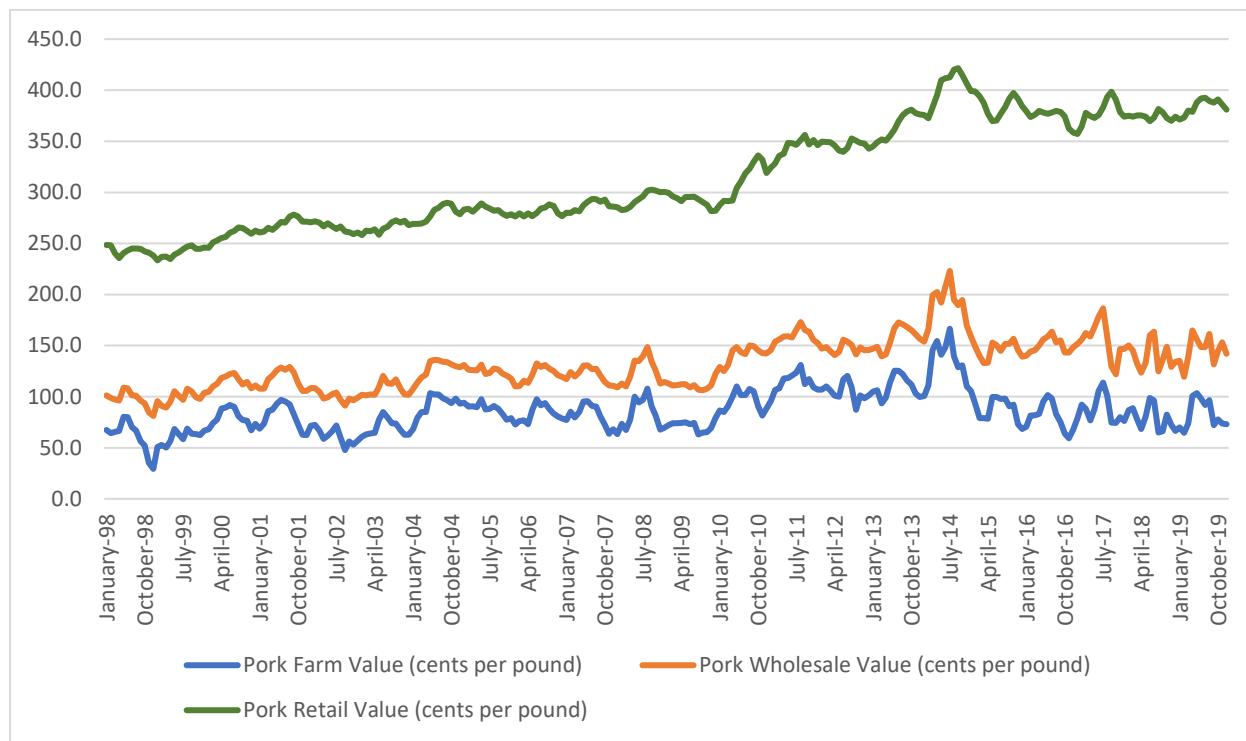


Figure 1. U.S. Pork Industry: Farm Value, Wholesale Value and Retail Value of Pork (1998-2019: monthly data). *Data source is USDA ERS (2021).*

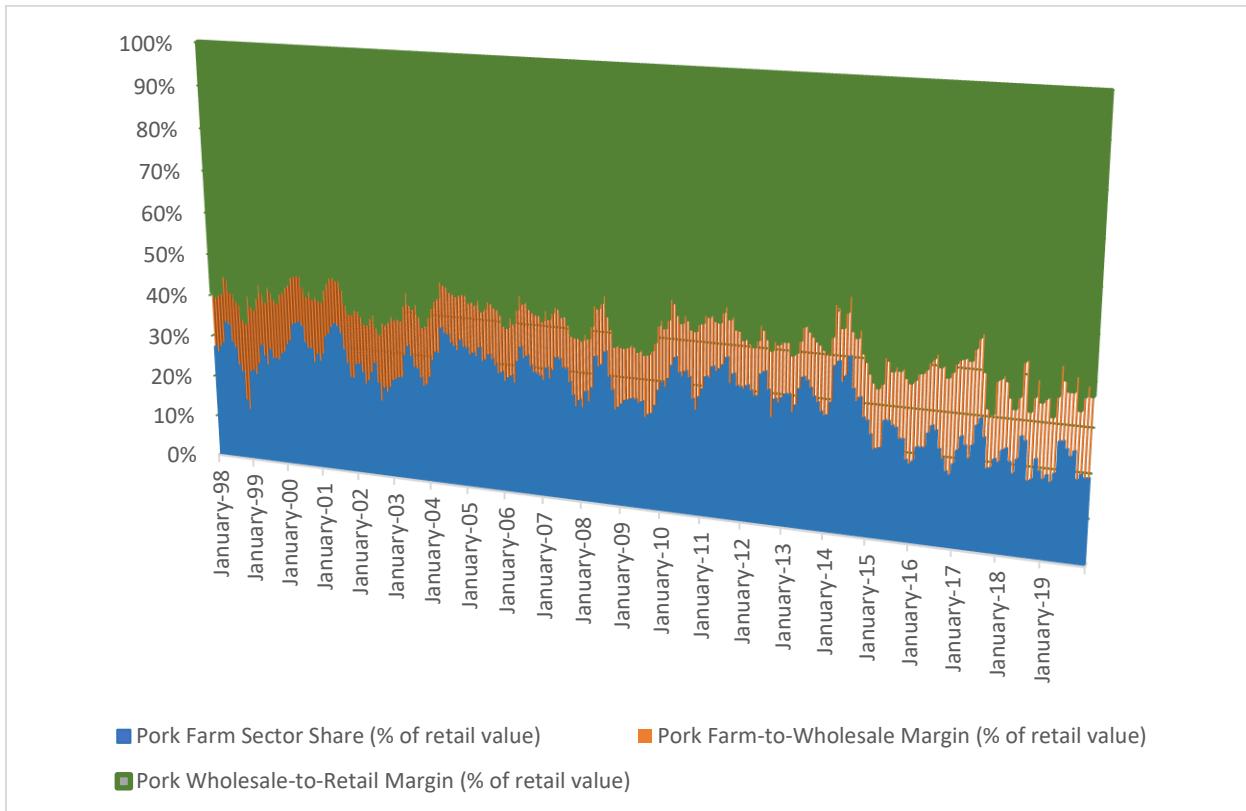


Figure 2. U.S. Pork Industry: Farm Sector Share, Farm-to-Wholesale Margin and Wholesale-to-Retail Margin as a Percentage of the Retail Value (1998-2019: monthly data).

The measures depicted in the figure are calculated by the author using farm, wholesale and retail values of pork reported in USDA ERS (2021).

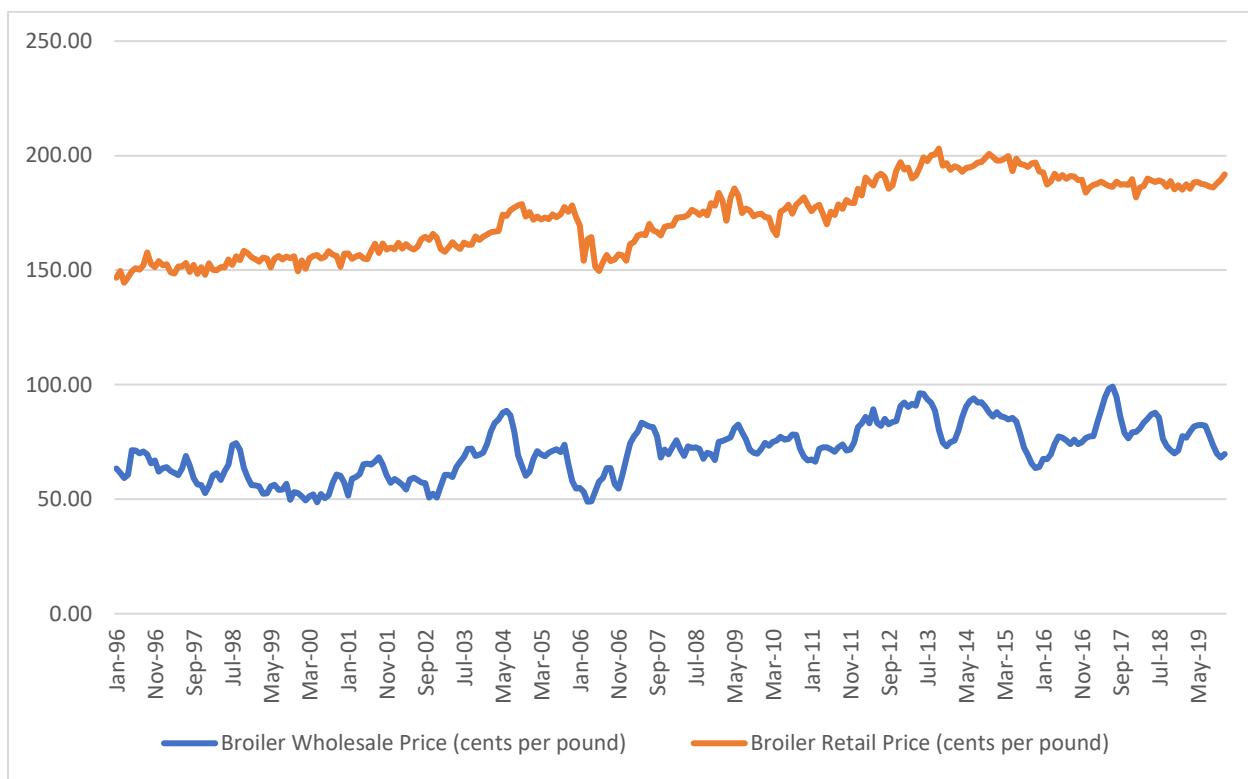


Figure 3. U.S. Broiler Industry: Wholesale Price and Retail Price of Broilers (1996-2019: monthly data). *Data source is USDA ERS (2021).*

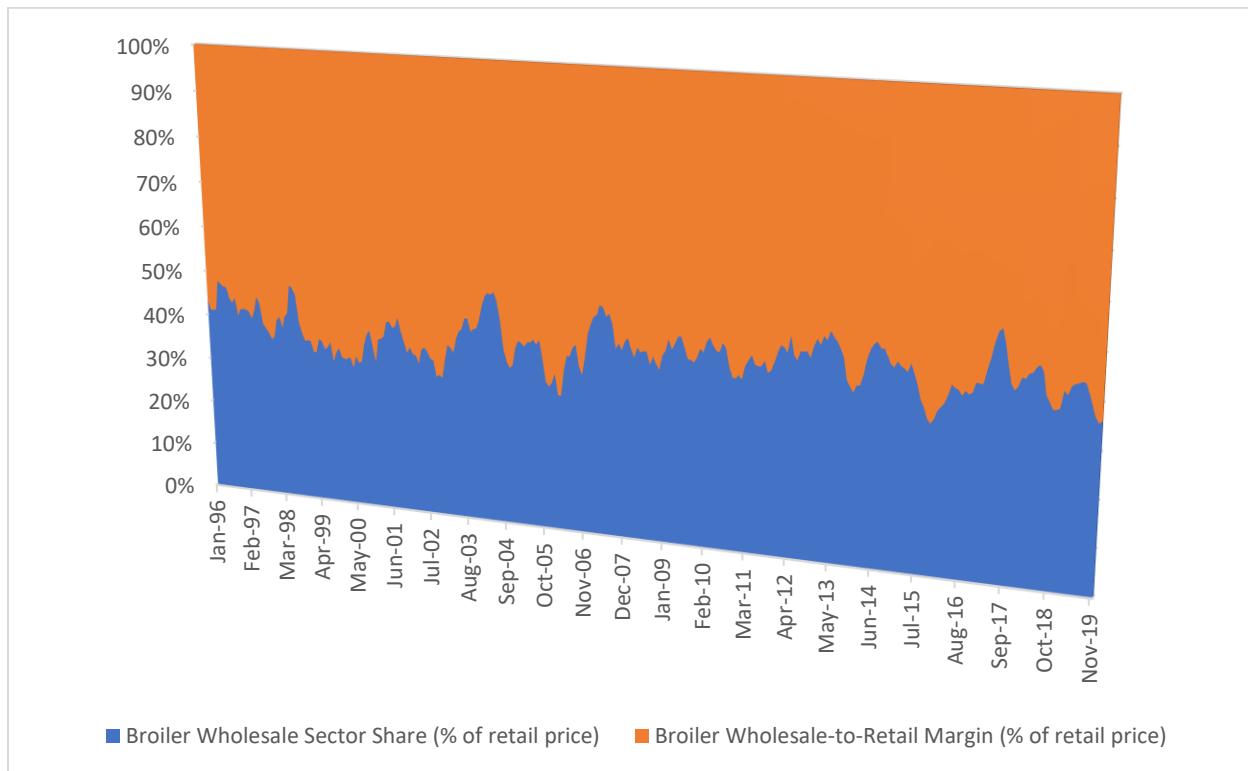


Figure 4. U.S. Broiler Industry: Wholesale Sector Share and Wholesale-to-Retail Margin as a Percentage of the Retail Price (1996-2019: monthly data).

The measures depicted in the figure are calculated by the author using wholesale and retail prices of broilers reported in USDA ERS (2021).