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Abstract

The objective of this study is to measure the amount of market power exercised by the U.S. red meatpacking industry using the recently developed stochastic frontier estimator of market power. The aggregate degree of market power in both the input market (cattle and hogs) and the output market (beef and pork) is estimated using annual time series data for the period 1970-2009. The empirical results reveal that the farm-to-wholesale price spread is 4.91% and 4.16% above the marginal processing costs, in the beef and pork packing industries, respectively. These findings indicate that rather a small percentage of the farm-to-wholesale price spread can be attributed to market power in both U.S. meat packing sectors.

Keywords: beef; pork; stochastic frontier analysis; market power

JEL classification: Q11, C13, L66.

1 Introduction

Red meat production is the largest segment in the agricultural sector of the U.S. economy and one of the most researched industries. It encompasses the farm-to-retail transformation of beef and pork.[1] The U.S. meat industry accounts for more than $100 billion (USDA 2014) in annual sales and half a million employees.

Over the last years, meat–packing firms have increased in size and scope through mergers, acquisitions and vertical coordination. More cattle and hogs are now procured through contracts, also know as captive supplies, giving rise to concerns that packers are “manipulating” cash prices in order to influence the base price used to negotiate contracts. As a result, the U.S. meat packing industry has many times been at the center of controversy regarding the conditions of competition in both the livestock procurement and wholesale meat markets (Azzam, 1998; Saitone and Sexton, 2012; U.S. Government Accountability Office (GAO), 2009).

Regarding the U.S. beef industry, between 1980 and 2012, the number of plants decreased from 704 to 168 and the four-firm concentration ratio (CR4) increased from 35.7% to 85% (United States Department of Agriculture – Packers and Stockyards Program, 2014). The CR4 has remained around 80% in the last ten years.[2] At the same time, the U.S. hog industry has also undergone major structural changes in the last 30 years. According to the Daily Livestock Report released by CME Group (2014), the top four packers control two thirds of the market.

Estimating the degree of oligopsony and oligopoly power along the U.S. meat supply chain has been the focus of many studies. The most influential research in the past few years has been the New Empirical Industrial Organization (NEIO), which is an econometric approach that treats market power as a parameter to be inferred from single industries data (Bresnahan, 1989). Azzam (1998) summarizes

[1] Red meat includes beef, pork, veal, lamb and mutton. Beef and pork account for more than 99% of the red meat production.

[2] Although concentration data are useful for describing an industry, high levels of concentration is not a sufficient condition to conclude that firms engage in non-competitive behavior (McCorriston, 2002).

the results of NEIO studies that tested for the presence of market power in both the input (livestock) and the output market (processed meat) in the meat, beef and pork packing industries. The majority of the studies report evidence of market power in the input and/or in the output market.

In the U.S. beef sector, Schroeter (1988) finds evidence of oligopsonistic and oligopolistic power exercised by beef processors. Azzam (1992) reports significant findings of oligopsonistic power but finds no evidence of oligopolistic power. Cai et al. (2011a,b) have concluded that processors exert oligopsonistic power when purchasing finished cattle for slaughter. In the U.S. pork packing industry, the empirical results of Azzam et al. (1989) reveal significant evidence of oligopsonistic as well as oligopolistic power exercised by pork processors. Schroeter and Azzam (1990) report statistical significant evidence of oligopsonistic power exercised by pork packing firms.

According to some studies, the magnitude of market power in the U.S. red meat industry is relatively small or is not large enough to warrant concern (Azzam and Schroeter, 1991; Schroeter, 1988; U.S. Government Accountability Office (GAO), 2009). But, as Sexton (2013) points out, even modest departures from perfect competition – relatively weak oligopoly or oligopsony power especially in the red meat industry – should matter. According to Ward (2010), a small degree of market power can translate into large transfers from livestock producers to packers: a seemingly small impact in dollars per hundredweight can make a substantial difference (losses) to livestock producers.

Lastly, there are studies that found no evidence of market power or concluded that the efficiency effects are larger than the market power effects of increased concentration (Paul, 2001a,b; Schroeter and Azzam, 1991; Sperling, 2002; U.S. Government Accountability Office (GAO), 2009).

In the light of the preceding, the objective of the present work is to estimate the aggregate degree of market power–oligopolistic and oligopsonistic– in the U.S.

beef and pork packing industries, with the use of the recently developed stochastic frontier approach (SFA) by Khumbhakar, Baardsen and Lien (2012).

In their original work, Kumbhakar et al. (2012) propose a new method of market power estimation. They draw on the stochastic frontier methodology from the efficiency literature in order to estimate mark–ups in the Norwegian saw-milling industry. The authors use both primal and dual specifications to represent the technology and consequently estimate the degree of oligopoly power. Both approaches reveal statistically significant evidence of market power. The primal and dual specifications of the technology is a big advantage of the stochastic frontier approach of market power estimation: in an output market, based on duality theory of cost and input–distance functions, either input price data or quantity price data can be used. On the other hand, duality of revenue functions and output distance functions can be utilized for an input market.

In the most recent and related study, Lopez et al. (2015) used the stochastic frontier approach in order to estimate oligopoly power in the U.S. food industry for the period 1979–2009. The stochastic frontier estimator of market power was evaluated with the use of panel data in 36 U.S. food industries at the four digit Standard Industrial Classification System (SIC) provided by the NBER-CES Manufacturing Industry Database. The estimated value of the overall mean degree of market power was found to be 6.4%, indicating that all 36 food industries, in the sample, exercise some degree of oligopoly power but quite moderate. In the meat–packing sector, the estimated value of the stochastic frontier estimator of market power was 0.037, indicating that the price of the meat output is 3.7% above the marginal cost of production.

To the best of our knowledge, there has been no published work which has used the stochastic frontier approach in order to explicitly estimate the degree of aggregate market power in the US beef and pork packing industries.

The present work is structured as follows: Section 2 contains the theoretical framework, Section 3 the aggregate model and Section 4 the data and estimation results. Conclusions are presented in Section 5.

2 Theoretical framework

2.1 Meat packing firm

The starting point of this study is the profit maximizing meat packing firm that produces either beef or pork.[3] Each firm purchases a homogeneous farm input x_i (cattle or hogs) and produces a homogeneous output q_i (beef or pork). On aggregate, the meat packing industry consists of N firms purchasing input X= $\sum_{i=1}^{N} x_i$ and producing good Q= $\sum_{i=1}^{N} q_i$. Packers have market power in the farm input market as well as in the processed output market.[4]

The supply function for the farm input is given by:

$$W = W(X) \tag{1}$$

where W is the price of input X.

At wholesale level, the inverse demand for the processed good is given by:

$$P = P(Q) \tag{2}$$

where P is the price of the processed meat output.

This article assumes fixed proportional relationship between the livestock and the processed meat output. Hence, farm and wholesale quantities can be measured, with

[3]Mergers and acquisitions in the U.S meatpacking industry have resulted in multi–output firms, i.e. firms slaughtering both beef and pork. The present study considers firms that produce either beef or pork. Hence, one could also assume the unit of analysis to be either the meatpacking plant or a single firm operating multiple plants.

[4]There are also high levels of concentration at the retail level of the meat industry. Accordingly, at the last stage of the meat marketing channel we find firms with potentially high degree of market power as well. This work focuses on the estimation of oligopolistic and oligopsonistic power exerted by meat processors and does not model for bilateral oligopoly power between packers and retailers.

appropriate conversion, by the same variable. Technology for each meat–packer is represented by the processing cost function C(q_i,r,t), where r is a vector of non-farm input prices and t captures the state of technology.

The profits for the i^{th} meat packer are given by:

$$\Pi_i = P(Q)\,q_i - C_i\,(q_i, r, t) - W(X)\,x_i \tag{3}$$

Each processor chooses q_i to maximize profits. The first order condition is:

$$\frac{\mathrm{d}\Pi_i}{\mathrm{d}q_i} = \frac{\mathrm{d}}{\mathrm{d}q_i}P(Q)\,q_i - \frac{\mathrm{d}}{\mathrm{d}q_i}C_i(q_i, r, t) - \frac{\mathrm{d}}{\mathrm{d}q_i}\,W(X)\,x_i = 0 \tag{4}$$

Taking into account that fixed proportions technology means $x_i = q_i$ and $X = Q$, equation 4 yields:

$$P - \frac{\lambda_i}{\eta}\,P - MC_i - W - \frac{\phi_i}{\epsilon}\,W = 0 \tag{5}$$

where $\eta = -\dfrac{dQ/dP}{Q/P}$ is the elasticity of demand of the processed meat–output, $\lambda_i = \dfrac{dQ/dq_i}{Q/q_i}$ is the conjectural variation elasticity for the i^{th} processor in the output market, $\epsilon = \dfrac{dX/dW}{X/W}$ is the elasticity of supply of the farm–input, $\phi_i = \dfrac{dX/dx_i}{X/x_i}$ is the conjectural variation elasticity for the i^{th} processor in the farm input market and $MC_i = C_i'(q_i, r, t)$ is the packer's marginal processing cost.

Re–arranging equation 5 we get:

$$(P - W) - MC_i = \frac{\lambda_i}{\eta}\,P + \frac{\phi_i}{\epsilon}\,W \tag{6}$$

The term in parenthesis on the left hand side of equation 6 represents the farm-to-wholesale price spread. The terms on the right hand side of equation 6 measure oligopolistic and oligopsonistic power respectively. The first term, $\frac{\lambda_i}{\eta}\,P$, accounts for the market power exercised in the output market by the i^{th} processor. Parameter λ_i captures the increase in total processed output induced by an increase in processor

i's output. The second term, $\frac{\phi_i}{\epsilon} W$, accounts for the market power exercised by the i^{th} processor in the input market. Parameter ϕ_i captures the increase in the supply of the farm input at industry level induced by an increase in processor i's demand for the farm input. The parameters λ_i and ϕ_i assume values greater than zero or equal to zero. In the case where both parameters λ_i and ϕ_i are zero, then there is no market power exercised by the i^{th} processor in the output market as well as in the input market. In this case, equation 6 is written as:

$$P - W = MC_i \tag{7}$$

The farm-to-wholesale spread is the competitive benchmark, i.e. price–taking packers receive a margin equal to their marginal processing cost indicating no market power exertion in the input market as well as the output market. On the other hand, oligopolistic and oligopsonistic distortions of equation 6 are captured by the terms $u_i^{oligopoly} = \dfrac{\lambda_i}{\eta} P$ and $u_i^{oligopsony} = \dfrac{\phi_i}{\epsilon} W$, respectively. Thus, equation 6 is written as:

$$(P - W) - MC_i = u_i^{oligopoly} + u_i^{oligopsony} \tag{8}$$

Both terms, $u_i^{oligopoly}$ and $u_i^{oligopsony}$, are non–negative. This allows us to write the following inequality:

$$(P - W) - MC_i \geqslant 0 \tag{9a}$$

$$P - W \geqslant MC_i \tag{9b}$$

Inequality 9b is analogous to the starting point of Kumbhakar *et. al.'s* (2012) theoretical model. Following their methodology, we multiply both sides of the inequality by $(\dfrac{q_i}{C_i})$ and add a non–negative term u_i. Hence, inequality 9b is converted into the following equality:

$$\frac{(P-W)\,q_i}{C_i} \quad = \quad \frac{\mathrm{d}\ln C_i}{\mathrm{d}\ln q_i} + u_i, \qquad u_i \geqslant 0 \tag{10}$$

The term u_i in equation 10 accounts for both oligopolistic and oligopsonistic distortions, since it is an increasing function of the terms $u_i^{oligopoly}$ and $u_i^{oligopsony}$. This way, u_i is a measure of the sum of the mark–up in the output market and the mark–down in the input market. Certain assumptions regarding the statistical distributions of the $u^{oligopoly}$ and $u^{oligopsony}$ terms would enable us to disentagle and uniquely identify market power in the output (beef/pork) and the input (cattle/hogs) markets separately. This approach is beyond the purpose of this article.

2.2 Translog processing cost function for the meat packing firm

In order to estimate the nonnegative one–sided term u_i of equation 10 we express the meat processing cost function in a translog form (Lopez et al., 2015) and follow Kumbhakar *et. al.'s* (2012) methodology. The non–farm factors of productions employed by meat packers at the processing stage are capital, labor, material and energy. The translog processing cost function for the i^{th} meat packing firm is assumed to take the following form:

$$
\begin{aligned}
\ln C_i \;=\; & \beta_0 + \beta_q \ln q_i + \frac{1}{2}\beta_{qq} (\ln q_i)^2 + \beta_{qt} \ln q_i \, t \\
& +\beta_{qk} \ln q_i \ln w_K + \beta_{qL} \ln q_i \ln w_L + \beta_{qM} \ln q_i \ln w_M \\
& +\beta_{qE} \ln q_i \ln w_E + \beta_t \, t + \frac{1}{2}\beta_{tt} \, t^2 + \beta_{Lt} \ln w_L \, t + \beta_{Kt} \ln w_K \, t \\
& +\beta_{Mt} \ln w_M \, t + \beta_{Et} \ln w_E \, t + \beta_K \ln w_K + \beta_L \ln w_L + \beta_M \ln w_M \\
& +\beta_E \ln w_E + \frac{1}{2}\beta_{KK} (\ln w_K)^2 + \frac{1}{2}\beta_{LL} (\ln w_L)^2 + \frac{1}{2}\beta_{MM} (\ln w_M)^2 \\
& +\frac{1}{2}\beta_{EE} (\ln w_E)^2 + \beta_{KL} \ln w_K \ln w_L + \beta_{KE} \ln w_K \ln w_E \\
& +\beta_{KM} \ln w_K \ln w_M + \beta_{LE} \ln w_L \ln w_E + \beta_{LM} \ln w_L \ln w_M \\
& +\beta_{ME} \ln w_M \ln w_E
\end{aligned}
\tag{11}
$$

where q_i is the processed meat (beef or pork) output, w_K=price of capital, w_L=price of labor, w_M=price of material and w_E=price of energy. The time index t is included to account for technological progress. We impose symmetry and linear homogeneity (Binswanger, 1974) in equation 11. Imposing symmetry means that: $\beta_{LK} = \beta_{KL}$, $\beta_{LE} = \beta_{EL}$, $\beta_{LM} = \beta_{ML}$, $\beta_{KM} = \beta_{MK}$, $\beta_{KE} = \beta_{EK}$ and $\beta_{ME} = \beta_{EM}$. In order to impose homogeneity, we normalize all prices with respect to the price of material.

Through equation 11, with symmetry and homogeneity imposed, the expression for $\dfrac{\partial \ln C_i}{\partial \ln q_i}$ is:

$$
\begin{aligned}
\frac{\partial \ln C_i}{\partial \ln q_i} = \beta_q + \beta_{qq} \ln q_i + \beta_{qt} \, t + \beta_{qK} \ln \frac{w_K}{w_M} + \\
\beta_{qL} \ln \frac{w_L}{w_M} + \beta_{qE} \ln \frac{w_E}{w_M}
\end{aligned}
\tag{12}
$$

Substituting equation 12 into equation 10 we get the stochastic version of the profit maximizing relationship for the meat packing firm:

$$\begin{aligned}\frac{(P-W)\,q_i}{C_i} &= \beta_q + \beta_{qq}\ln q_i + \beta_{qt}\,t + \beta_{qK}\ln\frac{w_K}{w_M} + \beta_{qL}\ln\frac{w_L}{w_M} \\ &\quad + \beta_{qE}\ln\frac{w_E}{w_M} + u_i + e_i \end{aligned} \tag{13}$$

The term $(P-W)$ is the farm–wholesale margin, as reported by the United States Department of Agriculture – Economic Research Service (2016a,b), for each one of the meat products of interest in this study. The composed error term $(u_i + e_i)$ in equation 13 is no different than the one from a stochastic cost frontier model. Equation 13 can be estimated using the maximum likelihood method which is commonly used to estimate a stochastic cost frontier. The maximum likelihood method is based on the distributional assumption of the errors. Following the literature (Kumbhakar et al., 2012; Kumbhakar and Lovell, 2003), the distributional assumptions regarding the terms u_i and e_i are: u_i is a normal variable truncated at zero from below, i.e. $u_i \sim N^+(0, \sigma^2_{u_i})$, and e_i is the usual two-sided normal noise term, i.e. $e_i \sim N(0, \sigma^2_{e_i})$. The present study assumes that the profit maximizing firm operates efficiently. Hence, unlike the stochastic frontier analysis approach, u_i does not measure inefficiency in production. Instead, it measures inefficiencies due to the firm's anti-competitive behavior. More specifically, the term u_i captures aggregate market power, i.e. the sum of oligopolistic and oligopsonistic power exercised by the meat packing firm. We will refer to u_i as the market power term or market power component.

2.3 Stochastic frontier estimator of the degree of market power

In a manner analogous to Kumbhakar et al. (2012), we measure the degree of market power exercised by the meat packing firm as:

$$\theta_i = \frac{(P-W) - MC_i}{MC_i} \tag{14}$$

The value of θ_i measures the degree of market power as the percentage difference between the farm–to–wholesale price spread and the marginal processing cost. If there is no market power presence, the farm–to–wholesale price spread is equal to the marginal processing cost and we get the relationship of equation 7. This result indicates that no market power is exercised by the i^{th} meat–packing firm in both the input and the output markets, since the value of θ_i is equal to zero.

Multiplying and dividing equation 14 by $(\frac{q_i}{C_i})$ we get:

$$\theta_i = \frac{(q_i/C_i)\big((P-W)-MC_i\big)}{(q_i/C_i)\,MC_i} \tag{15a}$$

$$\theta_i = \frac{u_i}{\partial \ln C_i \,/ \partial \ln q_i} \tag{15b}$$

Employing the expression of equation 15b along with the estimated value of u_i from equation 13, we can estimate θ_i as:

$$\hat{\theta}_i = \frac{\hat{u}_i}{\hat{\beta}_q + \hat{\beta}_{qq}\,\ln q_i + \hat{\beta}_{qt}\,t + \hat{\beta}_{qK}\,\ln\frac{w_K}{w_M} + \hat{\beta}_{qL}\,\ln\frac{w_L}{w_M} + \hat{\beta}_{qE}\,\ln\frac{w_E}{w_M}} \tag{16}$$

In the case where the i^{th} meat–packer exerts oligopoly and/or oligopsony power, the estimated value of θ_i will be greater than zero.

3 Aggregate model

The absence of panel data on firm-level suggests that we can neither estimate the market power term u_i nor the degree of market power θ_i for each individual meat packing firm. This limitation leads us to consider the problem at industry level, where aggregate data for the U.S. meatpacking sector are available.

Following the literature (Azzam and Andersson, 2008; Perloff et al., 2007), we multiplying through equation 6 by $(\frac{q_i}{Q})$ and summing across the N firms of the industry. This way, we obtain the aggregate supply relation:

$$(P - W) - MC(Q) = \frac{P}{\eta}\,\Lambda + \frac{W}{\epsilon}\,\Phi \tag{17}$$

In a manner analogous to Perloff et al. (2007) and Azzam and Andersson (2008) we define: $MC(Q) = \sum_{i=1}^{N} \dfrac{q_i}{Q}\, C_i'(q_i, r, t)$ as the weighted industry marginal processing cost, $\Lambda = \sum_{i=1}^{N} \dfrac{q_i}{Q}\, \lambda_i$ as the weighted conjectural elasticity in the output market and $\Phi = \sum_{i=1}^{N} \dfrac{q_i}{Q}\, \phi_i$ as the weighted conjectural elasticity in the input market. In all three relationships, the weights $(\dfrac{q_i}{Q})$ are each firm's market share in the output market (or in the input market since we assume fixed proportions technology).

Equation 17 is the industry analogue of equation 6. Just like equation 6, the two terms on the right hand side of equation 17 measure, respectively, oligopolistic and oligopsonistic power exerted by each U.S. packing –beef and pork– industry.

Equation 17 is written in the following form:

$$(P - W) - MC(Q) = u^{oligopoly} + u^{oligopsony} \tag{18}$$

where $u^{oligopoly} = \dfrac{P}{\eta}\,\Lambda$ and $u^{oligopsony} = \dfrac{W}{\epsilon}\,\Phi$.

Since both terms $u^{oligopoly}$ and $u^{oligopsony}$ assume nonnegative values, we can write the following inequality:

$$(P - W) - MC(Q) \;\geqslant\; 0 \tag{19a}$$

$$P - W \;\geqslant\; MC(Q) \tag{19b}$$

Multiplying both sides of the inequality by $(\dfrac{Q}{C})$ and convert the above inequality into an equality by adding adding a non–negative term u, we get:

$$\frac{(P - W)\,Q}{C} = \frac{\mathrm{d}\ln C}{\mathrm{d}\ln Q} + u, \qquad u \geqslant 0 \tag{20}$$

The term u in equation 20 is a function of both $u^{oligopoly}$ and $u^{oligopsony}$.

Representing the industry's processing cost function in a translog form and following the same procedure described in section 2, we arrive at the stochastic supply relation:

$$\begin{aligned} \frac{(P-W)\,Q}{C} &= B_Q + B_{QQ}\ln Q + B_{Qt}\,t + B_{QK}\ln\frac{w_K}{w_M} + B_{QL}\ln\frac{w_L}{w_M} \\ &\quad + B_{QE}\ln\frac{w_E}{w_M} + u + e \end{aligned} \tag{21}$$

The main difference between equation 13 and equation 21 is that the former is at firm level while the latter is at industry level. Estimation of equation 21 will provide us with the estimate of the term u at market level. After estimating the term u from equation 21, we can measure the degree of market power θ for the beef and pork packing sectors, respectively, as:

$$\hat{\theta} = \frac{\hat{u}}{\hat{B}_Q + \hat{B}_{QQ}\ln Q + \hat{B}_{Qt}\,t + \hat{B}_{QK}\ln\frac{w_K}{w_M} + \hat{B}_{QL}\ln\frac{w_L}{w_M} + \hat{B}_{QE}\ln\frac{w_E}{w_M}} \tag{22}$$

As equation 22 demonstrates, the estimate of the parameter θ depends on the estimated value of the term u as well as on the relevant parameters of the translog cost function.

4 Data and estimation results

The data used for the empirical analysis are annual time series for the U.S. beef and pork packing sectors for the time period 1970–2009. Data were obtained from the National Bureau of Economic Research–Manufacturing Industry Database (2016) for SIC2011 (meatpacking industry) and from the United States Department of Agriculture – Economic Research Service (2016a,b). A detailed description of the data and their sources can be found in the Appendix.

The non–farm inputs employed at the processing stage are divided into four categories: capital (K), labor (L), material (M) and energy (E). Price and quantity data on these factors of production are available for the U.S. red meat industry as a whole (NBER – SIC2011).[5,6] Capital is taken into account as a quasi-fixed input. The annual user cost of capital (w_K) was calculated as the sum of the real interest rate and the depreciation rate.[7] Time accounts for technological change and assumes the values between one (t=1) for the year 1970 and forty (t=40) for the year 2009.

Table 1 provides the definition of variables used in estimating equation 21 and presents their respective descriptive statistics for both packing industries examined in this study.

Table 2 presents the estimates of the parameters of the translog cost function employed in estimating equation 21, for the beef and pork packing sectors, respectively.

Table 3 presents the estimates and (bootstrap) standard errors of the aggregate degree of market power (θ) exercised by the U.S. beef and pork packing industries.[8] Estimates are statistically significant in both sectors.

In the U.S. beef packing industry, the estimated value of the degree of market power (θ) is 0.0491, suggesting that, on average, the farm-to-wholesale price spread is 4.91% above the marginal processing cost. In the case of the U.S. pork packing industry, the estimated value of the degree of market power (θ) is 0.0416. The value of θ indicates that, on average, the farm-to-wholesale price margin is 4.16% above the marginal processing cost.

The empirical results of this work suggest that rather a small percentage of the

[5] In order to quantitatively account for the quantity levels of K, L, M and E employed specifically for the production of beef and pork respectively, we multiply the aggregate levels of the aforementioned factors of production with the percentage of beef and pork output produced in relationship with the rest of the meat products.

[6] NBER-SIC2011 database reports deflators for the f.o.p. material and energy.

[7] Assuming a 20-year equipment working life in the food processing industry and a linear form, a value of 0.05 was applied to the depreciation rate (Lopez et al., 2015).

[8] The bootstrapped standard errors where obtained after 1000 repetitions.

farm–to–wholesale price spreads, in both the beef and pork packing industries, can be attributed to market power. These findings are comparable to studies that have concluded that the magnitude of market power is not big enough to warrant concern (Azzam and Schroeter, 1991; Schroeter, 1988; U.S. Government Accountability Office (GAO), 2009). Additionally, the results of this work are comparable to the findings of Lopez et al. (2015). In their study, the value of the SFA estimator of the degree of market power exercised in the U.S. meatpacking industry was as low as 3.7%.

On the other hand, the statistical significant findings of market power exertion should make researchers and policy makers pay also attention on the argument that even modest departures from perfect competition along the U.S. red meat marketing supply chain should matter. According to Ward (2010), even a small degree of market power can translate into quite significant welfare implications in the U.S. red meat packing sector.

Oligopsony power matters for market efficiency to the extent that the farm input is significant as a factor in producing the final product. Furthermore, if market power is exercised at multiple stages along the supply chain, deadweight (efficiency) losses can become quite significant, approaching one quarter of the total market surplus that would be available under perfect competition (Sexton et al., 2007).

From a policy perspective, market intermediaries with even a modest degree of market power can capture large shares of the benefits from policies intended to benefit producers of the farm/primary input. As Sexton (2013) points out, the distributional effects of market power exercised by market intermediaries are much greater than the pure efficiency consequences. Hence, specific policies that are designed to help farmers and quite frequently consumers, might not have the desirable effect due to the presence of modest amounts of market power.

5 Conclusion

The objective of this paper was to measure the aggregate degree of market power in the U.S. beef– and pork– packing industries with the use of the recently developed stochastic frontier estimator of market power. The theoretical model of this article allows the possibility to examine for the presence of aggregate market power in both the input (cattle/hogs) and the output (beef/pork) markets. The SFA estimate of market power provides us with a measure of the sum of oligopolistic and oligopsonistic power exerted by U.S. meat packers.

The empirical results of this study indicate that the U.S. red meat packing industry exerts rather a small degree of market power. In the case of the U.S. beef packing industry, the estimate of the degree of market power suggests that, on average, the farm–wholesale price spread is 4.91% above the marginal processing cost. In the U.S. pork packing sector, the estimated value of the degree of market power indicates that, on average, the farm–wholesale price spread is 4.16% above the marginal processing cost. Hence, based on the empirical findings of this study, we can conclude that only a small percentage of the farm–to–wholesale price margins, in both the beef and pork packing industries, can be attributed to market power.

The outcome of this study should be interpreted in light of data limitations and model construction. First of all, a more appropriate data set would contain information on the exact number of inputs employed exclusively for beef and pork production respectively. Unfortunately, annual data from the Census are available only for aggregate red meat output. Secondly, the relevant unit of observation in an imperfectly competitive model for the U.S. meat industry is the meat packing firm. Until data on firm level become available, aggregation is the only avenue in order to estimate the aggregate degree of market power exercised by meat packers when procuring live cattle/hogs and when selling beef/pork.[9]

[9] As Azzam and Pagoulatos (1990) point out, little can be known about how the presence or absence of market power is obscured by too much or too little aggregation.

Finally, one of the biggest challenges for future research is to develop a model where the oligopolistic and oligopsonistic distortions can be disentangled from each other and uniquely measured by the SFA estimator of market power. This would enable the researcher to test for market power in the output (beef/pork) and the input (cattle/hogs) markets separately. This means that one would be able to estimate an oligopoly and an oligopsony component, namely $u^{oligopoly}$ and $u^{oligopsony}$. Statistically significant estimates for these two terms would indicate the presence (or not) of market power in the output and/or in the input markets respectively. Among other things, certain assumptions for the statistical distribution of the $u^{oligopoly}$ and $u^{oligopsony}$ terms would be required.

Appendix

Description of the variables and their sources are as follows:

Source: NBER– CES Manufacturing Industry Database / SIC2011 (meatpacking)

$$L = \text{Production worker hours (million hrs)}$$

$$W_L = \frac{\text{Production worker wages (million \$)}}{\text{L}}$$

$$W_K = \text{interest rate} + \text{depreciation rate}$$

$$W_M = \text{Deflator for MATCOST (1987=1.00)}$$

$$W_E = \text{Deflator for ENERGY (1987=1.00)}$$

Source: United States Department of Agriculture – Economic Research Service

$$Q = \text{Commercial beef/ pork production (carcass weight, million lbs)}$$

$$(P - W) = \text{Farm–wholesale price spread (cents per retail pound equivalent)}$$

Tables

Table 1: Variable definition and descriptive statistics (equation 21)

Variable	Description	Mean	St. Dev.	Min	Max
Beef–packing industry:					
$(P-W)$	Farm–wholesale spread (cents/lb)	24.6981	7.8409	12.6417	41.5417
Q	Beef (billion lbs)	24.0809	1.7420	21.0890	27.0900
C	Cost (million $)	28.9923	6.1566	13.3224	39.2634
w_K	Price of capital	0.0443	0.0237	0.0001	0.0872
w_L	Price of labor ($/hr)	8.8326	2.4959	4.0386	13.7200
w_M	Price of material	0.9056	0.2050	0.4150	1.1660
w_E	Price of energy	1.0329	0.4231	0.2150	1.8210
t	Time trend (1=1970, 40=2009)	20.5	11.7	1	40
Pork–packing industry:					
$(P-W)$	Farm–wholesale spread (cents/lb)	29.7006	6.4591	19.8667	42.2750
Q	Pork (billion lbs)	16.6199	3.0849	11.3150	23.3469
C	Cost (million $)	20.3394	6.6155	8.3445	34.5104
w_K	Price of capital	0.0443	0.0237	0.0001	0.0872
w_L	Price of labor ($/hr)	8.8326	2.4959	4.0386	13.7200
w_M	Price of material	0.9056	0.2050	0.4150	1.1660
w_E	Price of energy	1.0329	0.4231	0.2150	1.8210
t	Time trend (1=1970, 40=2009)	20.5	11.7	1	40

Table 2: Parameter estimates of supply relationship (eq. 21)

Parameter	Est. value	Std. error
Beef–packing industry:		
$\hat{B}_Q$	120.89	7.72***
$\hat{B}_{QQ}$	−16.035	0.738***
$\hat{B}_{Qt}$	0.1996	0.0512***
$\hat{B}_{QK}$	−0.4087	0.3589
$\hat{B}_{QL}$	25.574	3.047***
$\hat{B}_{QE}$	−3.738	1.699**
Pork–packing industry:		
$\hat{B}_Q$	−81.934	5.820***
$\hat{B}_{QQ}$	1.019	0.392***
$\hat{B}_{Qt}$	0.018	0.057
$\hat{B}_{QK}$	−1.353	0.354***
$\hat{B}_{QL}$	44.054	2.979***
$\hat{B}_{QE}$	−17.781	2.093***

(’***’, ’**’, ’*’): 1%, 5% and 10% level of significance, respectively.

Table 3: Estimates of the degree of market power (eq. 22)

Parameter	Est. value	Std.error	95% Confidence Interval
Beef–packing insustry:			
Degree of market power ($\hat{\theta}$)	0.0491	0.0006	(0.0479, 0.0503)
Pork–packing insustry:			
Degree of market power ($\hat{\theta}$)	0.0416	0.0004	(0.0408, 0.0424)

Note: Standard errors were obtained with the bootstrap method.

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